What’s in a Map? Communicating Natural Hazard Forecasts

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Table of Contents

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Abstract

The number of people suffering from natural disasters, and the economic impact of those disasters, continue to increase. Better risk management strategies can help lessen the impacts of these disasters. One important aspect of risk management is communicating where potential hazards and risks may be located in space and time. Hazard maps are used by scientists and emergency management organisations to communicate hazard and risk information to people and organisations to warn and enhance preparedness for, and mitigate any impacts.

This research evaluated the effectiveness of communicating ashfall hazard through short-term ashfall forecast maps to a variety of specialist stakeholders in New Zealand. GNS Science currently produces short-term forecast maps for ash producing volcanic eruptions which are used by a wide range of specialist stakeholders for management of volcanic ash risk. A mixed-methods approach was used to evaluate what information should be provided in such a map according to 1) published literature on the topic; 2) the scientific information which could be provided, including the format according the map producer, GNS Science; and 3) information and format requirements by specific end-users of the maps, emergency management organisations and lifeline infrastructure organisations in New Zealand. Following the literature review (Stage 1), interviews were conducted with selected GNS scientists and selected end-users (Stage 2). After the data from the interviews was analysed, an internet-based survey was created and sent out to North Island based Civil Defence and Emergency Managers and Regional Lifelines Groups (group of critical infrastructure organisations) (Stage 3). At each stage a short-term forecast ashfall map template was designed from the research evidence. This evolved as further evidence was gathered and was customised to the New Zealand context.

This research found that there are seven basic elements which should be considered when creating a hazard map. These elements are: simplicity of the map, base map, map scale, the use of colour, geographical information, the inclusion of uncertainty, and time. This research also found key lessons which can be applied to any hazard map creation process. These lessons are: 1) communication between the information provider and the enduser is critical; 2) the information provider must decide between catering to the needs of the individual or the group; 3) education and outreach on behalf of the information provider are important; 4) audience feedback is necessary for an effective map; 5) established practices such as not using colour on the maps should be revaluated periodically; and 6) that hazard maps are just one step in the risk mitigation process, and should be accompanied by other activities such as public education programs and simulations.

List of Figures

List of Tables

Acronyms / Glossary

AELG: Auckland Engineering Lifelines Group

CDEM: Civil Defence and Emergency Management

Disaster: A serious disruption of a community or a society involving widespread human, material, economic or environmental losses or impacts which exceed the ability of the affected community or society to cope using its own resources (UN/ISDR, 2009).

Enduser: The person or organisation that will use the item/product being created.

GNS Science: New Zealand's leading provider of Earth and geoscience research, and the organisation mandated by the New Zealand government to provide natural hazard information and warnings.

Hazard: A potential threat to humans and their welfare arising from a dangerous phenomenon or substance that may cause loss of life, injury, property damage, and other community losses or damage (UN/ISDR, 2009).

Risk: The combination of the probability of a hazardous event and its negative consequences (UN/ISDR, 2009).

Risk Message: A message which conveys the probability of a threat or hazard being realised (Monmonier, 1997).

Stakeholder: A person or organisation with a vested interest in or concern about the outcome of a situation.

Vulnerability: The characteristic and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard (UN/ISDR, 2009).

WMO: World Meteorological Organization

Chapter 1 Introduction

As the population of the world continues to grow, so does the number of people exposed to natural hazards, such as volcanoes, earthquakes, and cyclones (ISDR 2009). With more people suffering the consequences of a natural hazard, the financial burden that natural hazards pose also continues to grow. Of the 25 natural disasters between 1975 and 2008 with costs totalling more than US$10 billion, 9 occurred between 2004 and 2008 (ISDR 2009). In 2011 and 2012, natural hazards caused a total of US$509 billion in damages (ISDR 2013). Better preparation and better risk mitigation strategies can help protect more people and bring the associated costs down, as well as improve the recovery effort. As the US Federal Emergency Management Agency (2011) states: "recovery begins with pre-disaster preparedness and includes a wide range of planning activities."

The international road map to improve natural hazard risk mitigation is given by the Hyogo framework for action 2005-2015 (ISDR 2005). The framework's second priority is to "Identify, assess and monitor disaster risks and enhance early warning". Identification and assessment of hazard is the process of using all available methods to determine the location, intensity, frequency and probability of potentially hazardous event. Risk assessment is "a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend" (UNISDR 2009). Knowledge of hazard and risk information allows risk managers to undertaken actions which mitigate or prepare for the adverse effects and losses caused by the hazard. A common way to depict hazard and risk information in a systematic and comprehensive way for risk managers is by utilising visual tools, such as hazards maps. A hazard map can be defined as graphical representation of the geographical distribution of the various potential hazards for a given geography area that would be exposed if the hazardous event occurred. The hazard(s) maps may also include a temporal component or probability and depict societal elements which may be vulnerable to impact from the hazard. Hazard maps typically use ‘zones’ to classify different scales of hazard, which may be defined by probability of occurrence, intensity, magnitude and/or hazard type.

A “hazard map” is a broadly used term which has been used to describe a variety of different map types which depict hazard and/or risk information. The Australian Geomechanics Society landslide standard (2007) offers the following definitions:

- Inventory maps: catalogue of past hazardous events.
- Susceptibility maps: includes both past events, and those which may potentially occur in the future (Includes: ‘scenario-based maps’)
- Hazard maps: created by adding an estimated frequency, i.e. probability, to susceptibility maps
- Vulnerability maps: includes elements that may be impacted by a hazardous event, e.g. infrastructure
- Risk maps: most complex spatial representation of hazard and vulnerability, incorporating loss probability

Haynes et al. (2007) clearly delineate the usefulness of hazard maps when they described their use for volcanic hazards: “hazard maps have become a fundamental means of communicating volcanic risk to the public. They are used to explain and display the distribution of hazards, risk levels of areas likely to be affected, and areas where access may be denied in times of crisis.” Hazard maps can also help a community determine where to place their resources to make sure that they are not at risk from future hazardous events (Corpuz 2003).

Hazard maps play a critical role in the hazard assessment process. To assess how a natural hazard will affect a community or an organisation’s assets, a hazard manager must analyse all of the pertinent data regarding the hazard. In the Hyogo framework for action 2005-2015 (ISDR 2005) it states that "both communities and local authorities should be empowered to manage and reduce disaster risk by having access to the necessary information, resources and authority to implement actions for disaster risk reduction." Information concerning the hazard must be made available to all the necessary groups so that everyone can create plans specific to their area and keep them current. The Encyclopedia of Natural Hazards (Bobrowsky 2013) lists several ways this information can be gathered:

- Field mapping and/or use of aerial photography and remote sensing data to establish the geology, geomorphology, topographical characteristics, and vegetation cover.
- Collecting samples of soils or water to determine engineering or geochemical characteristics.
- Examination of historical documentary data on hazardous events to determine the magnitude and frequencies.
- Mapping of former or current uses of land.
- Assembly of information on factors that trigger or exacerbate hazards.

The information is often then synthesized into a map in order to present a visual representation of the hazard and how it will affect its surroundings. Usually this gathering and synthesisation of data will be conducted by an official agency, but not always. A hazard, risk or emergency manager will use the map to help answer questions such as:

- How likely is the event to occur?
- If it does occur, where will the impact be the greatest?
- What will those impacts be?

The hazard manager must then determine what, if any, steps should be taken to mitigate the effects of the hazard.

Many hazard maps are the results of models which simulate the hazards, often by computing the physics of the event (Bobrowsky 2013). The maps display the final output of the models. Hazard maps can be one of two types, either probabilistic or deterministic. Each type has its benefits and drawbacks for assessing the impacts of a natural hazard. Probabilistic maps (for an example of a probabilistic map see Figure 2.3) are created by running an algorithm or a simulation many times and combining the output of each run into a single end result (Haneberg 2000). The algorithm/model is designed to allow and account for variability, and therefore the final output has the potential to be different each time. This is accomplished by allowing the inputs to be chosen from a specified range, and with a specific distribution. When these results are combined into a single map it shows how often each area reached a certain threshold or experienced a certain effect (whatever the parameter being tested is). Thus, these maps show the probability of a certain result occurring. Probabilistic maps can be designed to show results for any time frame, long or short. These are the types of maps that land use planners commonly incorporate into their decisions. For example, a land use planner in Los Angeles, California, an area with a high seismic hazard from multiple fault sources, might refer to a probabilistic earthquake hazard map which shows how likely an area is to experience a certain level of shaking (with associated uncertainty) within a specified return period, such as within the next 500 years. This helps the planner to determine which types of activities would be safe to do in that area and which ones would not.

Deterministic maps (for an example of a deterministic map see Figure 2.2) are scenario-based and usually display a single expected outcome. The algorithms or simulations behind deterministic maps do not account for variability, but instead rely on specific inputs. These maps are used to display the expected outcomes of specific settings (Haneberg 2000). Deterministic maps can also be designed to show results for any time frame, but due to being scenario-based they are most commonly used for short-term maps. An example of a deterministic hazard map is the map that a news station puts up when reporting on a hurricane (which is provided by the pertinent meteorological organisation). The map shows the projected path of the hurricane, based on the current conditions (see Figure 2.2). Probabilistic and deterministic hazard maps fill different criteria, and thus there is a need for both.

1.1 The context for this research

One application of hazard maps is to communicate short-term natural hazard information. This can include, but is not limited to, forecasts for volcanic ashfall, flooding, lahars, and hurricanes. In New Zealand, GNS Science (hereafter referred to as GNS) is the organisation that has been tasked by the government to communicate such information for geological hazards (such as earthquakes, volcanic eruptions, landslides, tsunami, etc.) to pertinent stakeholders and to the public in general. This provision of natural hazard forecast data is part of a general strategy which consists of GNS communicating natural hazard and risk information to the public (Civil Defence & Emergency Management 2009). This is conducted to inform better decision-making and make for a resilient New Zealand.

The CDEM Act 2002 states that the primary goal for communities to be self-reliant, which includes the communities "aiming to reduce the likely impact of, prepare for, and be able to respond effectively to emergency events" (Finnis 2004). To achieve this goal the communities must be aware of the natural hazards present in New Zealand, and how those hazards might affect them. The key to this awareness, and therefore greater resilience, is communication and education (Finnis 2004). One of the hazards that the communities must be aware of is volcanic ashfall. The manner in which GNS communicates short-term volcanic ashfall forecasts is via a deterministic ashfall forecast map (Figure 1.1). This hazard map is generated by a modelling program named ASHFALL. ASHFALL is a simulation which takes into account variables such as, but not limited to, eruption column height, grain size distribution, and current and forecasted wind patterns. It takes the input parameters and uses them to rapidly calculate how the ashfall will be deposited. This map was created in response to the need in New Zealand for a rapid assessment of ashfall following an eruption, and was first tested on a large scale in the 1995-1996 Ruapehu eruptions. Following the 2012 Tongariro eruption it was decided that it would be useful to re-examine the ashfall forecast map to determine if it was still effective. As such, the ashfall forecast map generated by ASHFALL will be the focus of this research.

Since a hazard map must be cartographically sound in order to be effective, the general features of an effective map will be briefly summarised. First, the layout of the map must be clear and clutter free. Next, the colours chosen should reflect the message or information that the map is conveying. Third, the symbology used should be items that the audience will be familiar with. Finally, ensure that the map contains all of the basic elements, such as a scale bar, north arrow, and legend (Peterson 2009).

1.2 Research aims

The aim of this thesis was to investigate what makes an effective short-term natural hazard forecast map, specifically with references to ashfall hazards in New Zealand's North Island. It was hoped that information would be gathered which can be of help to the hazard forecasting community in general. Also, any specific improvements that can be made for ashfall forecast maps in the New Zealand will be discussed. The end product of this research was what is considered an optimal short-term volcanic ashfall forecast map for New Zealand. To reach this goal a list of objectives was set forth. Those objectives were:

1. Determine what volcanic ashfall hazards information major stakeholders would be interested in receiving immediately following an eruption.
2. Determine what major stakeholders want from an ashfall forecast map.

3. Determine if the ASHFALL generated map can be better optimised to meet their desires.

1.3 Thesis Summary

The structure of this thesis, is as follows:

- Chapter 1 Introduction
    - Basic context and the rationale for this research
- Chapter 2 Literature review
    - An in-depth description of what a hazard map is
    - A review of past research with regards to the elements of a hazard map
    - A review of the creation process of a hazard map
- Chapter 3 Methodology
    - The methodological process for this research is presented
    - Three different methods of information gathering were employed: literature review, interviews, and an internet-based survey
    - After each round of information gathering the ideal/optimal map design was updated accordingly
- Chapter 4 Results
    - Each iteration of the short-term volcanic ashfall forecast map is presented with the justifications for the changes in that version
- Chapter 5 Discussion and Conclusions
    - Findings are discussed
    - General lessons which can be learned from this research
    - Strengths and weaknesses of the chosen methodology are discussed

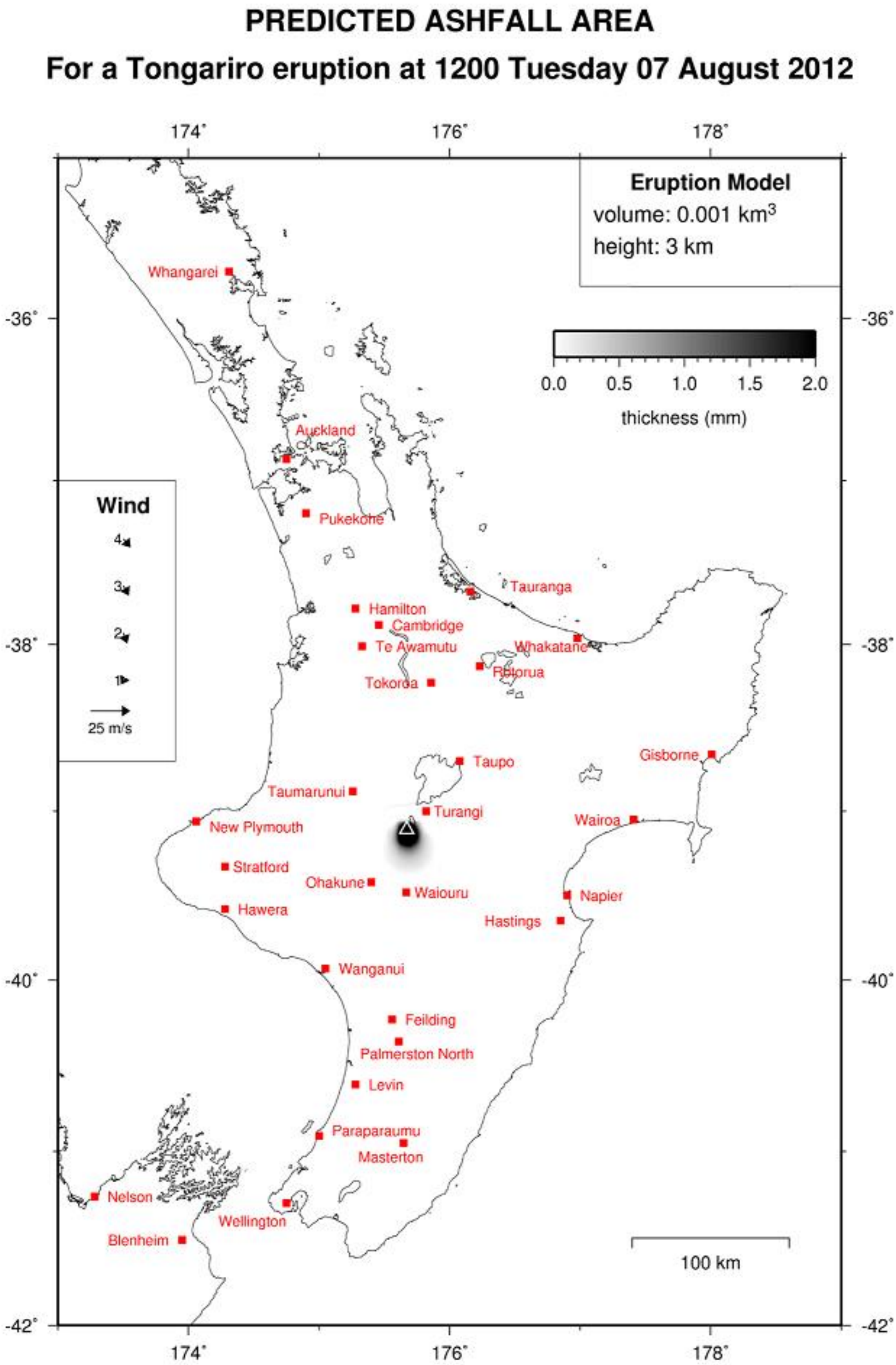


Figure 1.1: GNS-produced ashfall forecast map of a small hypothetical eruption, which was created for training purposes.

Chapter 2 Literature Review

The purpose of Chapter 2 is to review current ‘best practise’ for short-term natural hazard forecast maps. This review is broken into the following sections:

- What is a hazard map?
- Advantages and Disadvantages of hazard maps
- Key elements of hazard maps
- Uncertainty
- Motivating people
- Participation in the process
- Summary

Together these sections will identify why hazard maps are used, what the basic elements of hazard maps are, and what is taken into consideration during the creation of a hazard map. The review finishes with a general summary of what has been determined by a study of the available literature.

2.1 What is a hazard map?

Put simply, a hazard map is a map that indicates the hazard present at a specific location (Alexander 1993). Lindell, Prater, and Perry (2007) define a hazard as “a source of danger or an extreme event that has the potential to affect people, property, and the natural environment in a given location.” Therefore, a hazard map is a visual representation of a source of danger or extreme event and its spatial surroundings. The objective of a hazard map “is to provide residents of the area with the information on the range of possible damage and the disaster prevention activities” (Udono and Sah 2002). Put more colloquially, a hazard map is a map which shows the reader which areas of a region are likely to experience the effects of the hazard (and to what degree). A hazard map cannot stop the disaster, but the effective use of one can decrease the magnitude of the impact.

The benefits of effective hazard maps can be far reaching. Hazard maps can provide input "to educational programs to illustrate local hazards, to scientists studying hazard phenomena, land use planners seeking to base settlement locations to reduce hazard impacts and to combine with other information to illustrate community risks" (Noson et al. 2002). All credible hazard maps are either created by using a model to compute likely outcomes of a specific hazard scenario, synthesising historical data of past hazard events in that area, or using information regarding the current situation as it pertains to the hazard being mapped (Alexander 1993; Monmonier 1997). As a result of this, every hazard map will have some degree of uncertainty associated with it (as will be discussed Section 2.4). Wu et al. (1996) state that "an ideal hazard map should provide information relating to the spatial and temporal probabilities of the hazard mapped." Udono and Sah (2000) list 5 types of information which are needed to mitigate a disaster, which a hazard map can help convey:

What: What kind of hazard occurs?

Where: Where does the hazard occur? How extensive is the range?

How: How large is the scale of the hazard? How intense is it?

When: When has the event occurred or when is it likely to occur?

Who: Who is in danger because of the hazard?

Some examples of different types of hazard maps are:

- Landslide hazard: Some landslide hazard maps take into account historical averages of past events over thousands of years and show a conglomerate of all possible outcomes and the likelihood. These types of maps can be used to inform land use planning. See Figure 2.1 for an example map.

- Hurricane forecast: This type of map uses data from current situations and only displays the expected impacts of that specific scenario. They can be used to see which areas are most likely to be impacted in the near future and inform emergency preparation decisions and recovery efforts. See Figure 2.2 for an example map.
- Tsunami inundation maps: These maps are often based on a combination of data from historical events and probabilistic models of future events. They can also be used to inform land use planning for both the long-term and the short-term. See Figure 2.3 for an example map.

Some other types of hazard maps are: volcanic impacts maps, shake maps (earthquakes), liquefaction hazard maps, extreme temperature maps, etc.

This review will show that the creation of a hazard map is a process. The first part of the process is information gathering. Information regarding past occurrences of the hazard and, the current situation, and the exposure of people and/or assets is collected. The second part of the process is taking that information and determining which parts of it are pertinent to the intended audience, and what method of display is most effective. To accomplish this part the creator of the map must communicate with the intended audience to ensure that their needs and preferences are accounted for. It is also critical to communicate with the audience to ensure that the risk management strategies that will be developed from this information are feasible. The final product may be different for each hazard, location, and audience. However, despite every hazard map being unique, they share similar basic elements, such as the inclusion of a base map, the marking of the hazard zone, etc. The remainder of this chapter will first present these basic elements and the various possibilities regarding them, then review the different aspects which make each map unique such as how to motivate a target audience and taking the audience feedback into account.

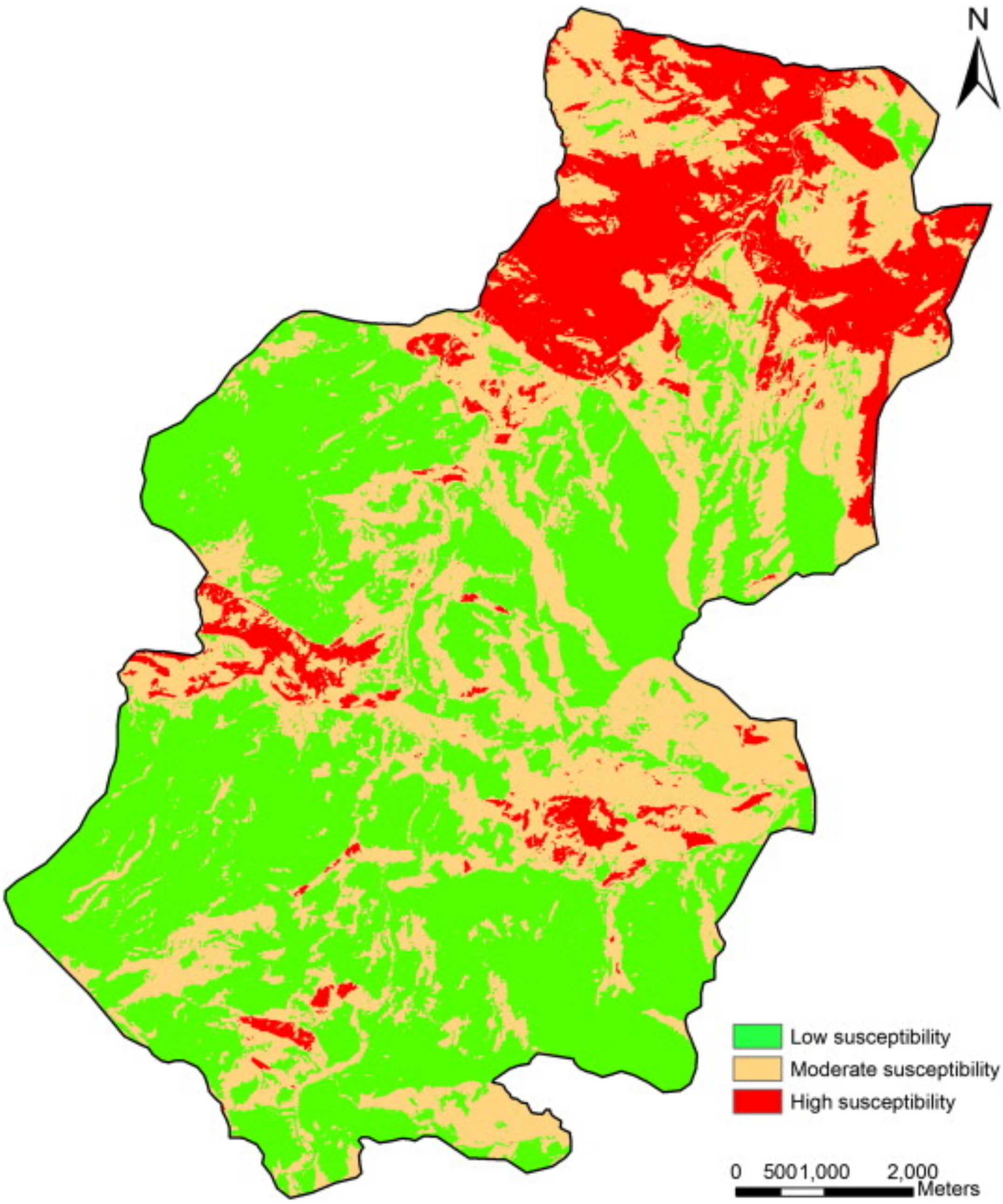


Figure 2.1: Example of a landslide hazard map (Martha et al. 2013).

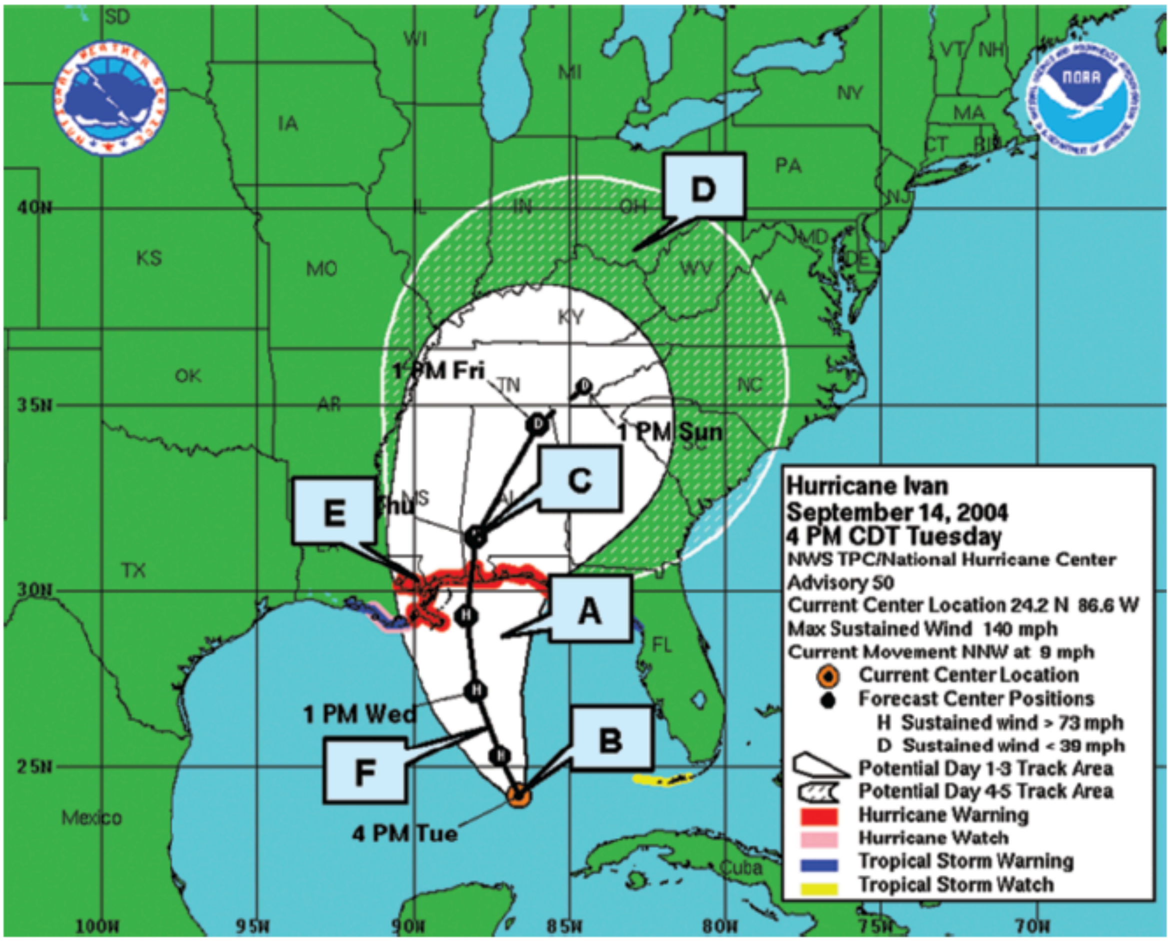


Figure 2.2: An example of a hurricane forecast map (Broad et al. 2007).

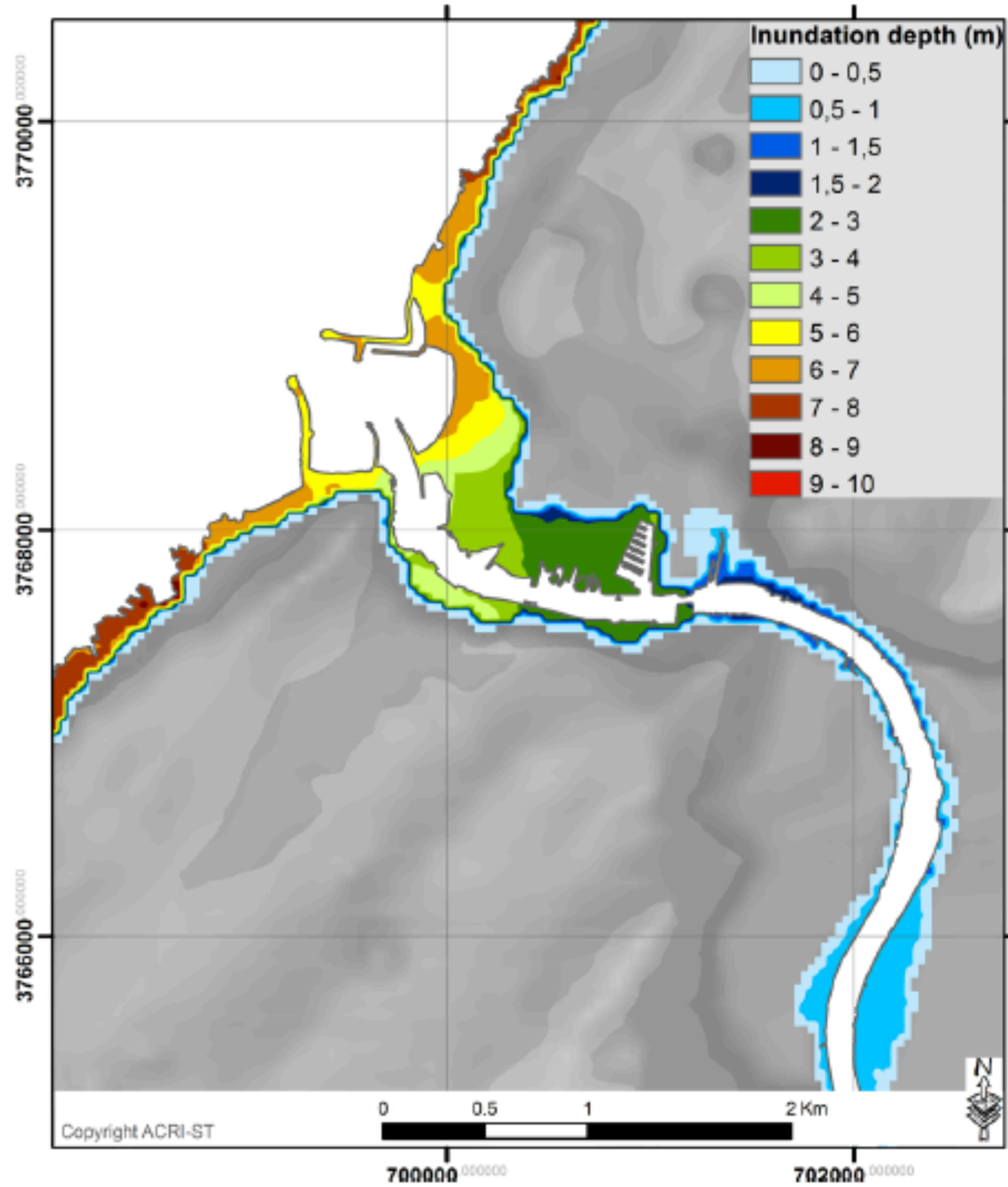


Figure 2.3: Example of a tsunami inundation map (Renuo et al. 2011).

2.2 Advantages and disadvantages of hazard maps (and their use)

Hazard maps are an essential component of an effective natural hazard response, as will be shown. Communicating risk messages by displaying them on a map is an approach which is increasing in frequency (Moen and Ale 1998). As was stated in the introduction of this thesis, there are many benefits to using a map to convey the hazard information, such as the ability to depict the spatial distribution of the hazard and places of interest, and helping communities determine where to place their resources. Haynes, Barclay, and Pidgeon (2007) explain the role of hazard maps in the volcanic hazards maps: "hazard maps are considered essential tools in the communication of volcanic risks between scientists, the local authorities, and the public." Gruber and Margreth (2001) show how important hazard maps are with regards to avalanches when they describe how the reduction in damages and deaths in Switzerland due to avalanches have gone down as a result of better hazard mapping. Corpuz (2003) summarises the benefits of hazard maps when he writes:

> Hazard maps provide a concise and simplified way of directly showing specific hazards and the extent of possible or probably [sic] damage. Hazard maps, when properly explained, directly guide authorities to concentrate precious resources to priority areas. Maps are the only way to show and explain boundary zones on safety and danger." (page 81)

Haynes, Barclay and Pidgeon (2007) support this view when they write that the role of a hazard map is to both explain and display the distribution of hazards, as well as to show the level of risk associated with areas likely to be affected. They also explain that hazard maps form an integral part of both emergency planning and emergency response as they are used to coordinate preventative, protective, and rescue evacuations.

Describing one use for hazard maps, Alexander (2004) explains that "in any sudden impact disaster one of the first requirements is to understand the geography of the affected area. This includes its dimensions and boundaries, and the position of lifelines, critical facilities and cardinal points such as large collapsed buildings, fires, and the possible location of trapped victims." Alexander goes on to point out that "many local emergency responders have good geographical knowledge of the areas in which they operate, but they are never likely to have perfect recall of the full catalogue of elements of the physical and human landscape and the distances that separate them from each other." With these two ideas Alexander shows how hazard maps can help lead to a more effective response to an emergency situation. There needs to be a concrete visual image to reference because "knowledge, experience, character, personality and perception all produce discrepancies between a person's mentally stored image of a landscape and the real situation as depicted by a topographic map" (Alexander 2004).

Just as any other method of communication, hazard maps also have their drawbacks as well. Bell (1999) states one of their drawbacks when he states that they are "highly generalized and represent a static view of reality." He also explains that they need to be updated regularly as new data on the hazard becomes available. He uses Mount St Helens as an example, explaining that the hazard maps had to be completely recreated after the eruption in 1980. Another disadvantage of hazard maps is that their effectiveness is completely dependent on how much trust the audience has in the organisation publishing the map (Monmonier 1997). Others feel that the biggest drawbacks of hazard maps are due more to their design. With respect to volcanic hazards, Nave et al. (2010) write that "recent studies have shown that volcanic hazard and risk maps are difficult to interpret, limit understanding and consequently preparedness to react both to changes in volcanic activity and the management of the emergency may be compromised, even when users have high levels of education.” They contend that volcanic hazard maps need to be designed in a manner which is more readily understood by the intended audience, and proceed to redesign the hazard maps for the island of Stromboli, Italy according to what they deem is best practice. In their paper they recognise the important role that volcanic hazards maps play while arguing that it still needs improvement, as recent studies have shown that volcanic hazards maps can be difficult for the audience to interpret due to poor design (Nave et al. 2010; Moen and Ale 1998). Despite this noted need for improvement, it is clearly demonstrated throughout the literature that hazard maps should and often do play a critical role in any natural hazard situation, whether it be planning for or responding to an event.

2.3 Key elements of hazard maps

Now that it has been established what a hazard map is and the important role that they play, the next topic to be reviewed will be the key elements of one. These elements can be found in all hazard maps, though the ways that they are presented will differ. No definitive answer or single solution will be given for these elements, as that depends on the individual circumstances of each map (as will be discussed later in this review).

To start, the quantity of information contained on the map has been addressed. Although one might think that the more information that is provided, the better the hazard planning and response can be informed, research has shown that this is not the case. Broad et al. (2007) discuss changes which have taken place in hurricane mapping in the recent past and conclude that the “more information is always better” argument is not valid. Referencing Tufte (1983), they argue that “more information packed into a graphic is often confusing (Tufte 1983), and when people misunderstand the information, it can lead to flawed decision making...” (Broad et al. 2007). Kunz and Hurni (2008) put it clearly when they state, “a decrease of the level of complexity would lead to a better understanding.” While discussing flood hazard maps in Switzerland, Kunz and Hurni (2008) also state that if too much is included in the map it becomes confusing and even subject matter experts can have trouble understanding a clear picture of the situation. They suggest that a decrease in complexity would result in a better understanding of the map. Doyle and Johnston (2011) also agree, writing that "it is not just a case of providing the emergency managers with all the available scientific information... Simply providing as much advice as possible may actually hinder the decision process due to cognitive overload and an overuse of these available resources." Leitner and Buttenfield (2013) suggest that even if the user of a complex map is able to comprehend all of it, they will "need more time to mentally process the additional information and thus will prolong the time to make... decisions." Clearly it has been shown across multiple hazards that hazard maps must avoid becoming overly complex if they are to be useful, and these authors are supported by many others (Nave et al. 2010; Haynes, Barclay, and Pidgeon 2007; Moen and Ale 1998). In an attempt to identify the key elements that are required of a hazard message, Drabek (1999) lists seven questions a hazard message must answer to be effective (these topics and others will be addressed):

- Who is issuing the warning?
- What is threatening?
- What exact geographical area is threatened?
- When is it coming?
- How probable is the event?
- Are there risk locations, such as people in automobiles, which require special actions?
- What specific protective actions should be taken?

The remainder of this section has been dedicated to reviewing the different elements of short-term natural hazard maps and how each element is best accomplished. One must maintain in their mind the ideas raised earlier concerning avoiding cognitive overload and ease and speed of interpretation while discussing these elements.

2.3.1 Base map

The first element of the map to be addressed is the most fundamental, which is the background, or the base map. The base map should be one which will most effectively convey the necessary information to the intended audience, and that will vary with who the intended audience is, as is shown by the different results gathered by Haynes, Barclay, and Pidgeon (2007), Nave et al. (2010), and Leonard et al. (2008). Haynes, Barclay and Pidgeon (2007) conducted surveys on the island of Montserrat in the West Indies and one of the topics that they investigated was how well local residents could locate themselves and well-known geographical features on different types of maps. They found that the residents were significantly more proficient with aerial photographs than with 3D maps or contour maps. Nave et al. (2010) conducted similar research on the island of Stromboli, Italy, and found that when they surveyed a group of people who were trained in understanding and interpreting contour maps "most respondents (12 out of 13) expressed a preference or a strong preference for personally using contours maps, but suggested the plan-view aerial photograph was more suitable for distributing information to the general public (8 out of 13)." Another similar research project conducted along a hiking path in New Zealand found "a plan-view map to be significantly more effective than an oblique photo" (Leonard et al. 2008), and it was suggested that this was due to the survey being conducted along a hiking path which meant that many of the respondents were hikers who commonly used plan-view maps to plan their trips. Together these papers show the importance of seeking audience feedback and tailoring the final product to the intended audience. Each group of researchers came to a different conclusion as to which map style was better because they were working with different people who had different needs and different levels of expertise.

2.3.2 Map scale

Another important component of hazard maps is the scale of the map. For clarification, a large-scale map is one that covers a smaller amount of area than a small-scale map (e.g. 1:100 versus 1:10,000 respectively). The scale must be appropriate for the size of the event or it will be harder to interpret, as either the resolution will be too poor (small event shown on a small-scale map) or the map will not encompass the whole event (large event shown on a large-scale map). Moen and Ale (1998) state "the relevance of entities for which the spatial extent is small... is difficult to convey on a map also showing entities with the large spatial extent." If the agency responsible for distributing hazard information wishes to display both large and small events, they should conduct research with the intended audience to determine what manner is most effective for them (two maps, one map with an inset showing the small event, etc.).

2.3.3 Colour

Colour, if used appropriately, can greatly increase both the aesthetic quality and the effectiveness of a hazard map (Chesneau 2011). However, it must be used cautiously. Overuse of colour can be a detriment to the map, causing it to be too complex (Severtson and Myers 2013). Nave et al. (2010) directed their surveys on the island of Stromboli, Italy to those who would be in a position to pass on information during a time of crisis (e.g. civil protection officers, volcano guides) and found that the inclusion of colour in the maps was frequently suggested by the respondents as a way to improve the maps. Nave et al. (2010) took the information gathered and used it to create a new set of hazard maps which they then displayed. After displaying the new maps they conducted a survey about them. They found that "one of the features most commented on for the second generation of maps was the use of colour", but they also warned that "colour should be used very sparingly so as to not confuse the map." However, Nave et al. do not go on to discuss the effectiveness of the inclusion of colour, which would have been useful as MacEachren et al. (2005) found that even though a user prefers a certain method, it does not mean that they will have more success with that method. This idea of colour being beneficial when used correctly is present in other hazard fields as well. In the Guidelines on Communicating Forecast Uncertainty produced by the World Meteorological Organization (hereafter referred to as the WMO) it states that “colour is a very powerful tool for conveying information and meaning. Like any tool, it needs to be used carefully” and that “great care should be taken that the colours that are chosen send the right message” (Kootval 2008). Kootval (2008) goes on provide an example of certain colours causing subconscious reactions due to the setting. He provides a map where 49% probability of rain is marked in yellow and 51% probability is marked in green. He points out that in this setting, yellow is often thought of as dry while green is through of as wet, so while 49% and 51% are numerically very similar, the areas look very different concerning probability of precipitation on the map. Kootval (2008) also points out that it is important to consider people with colour blindness when choosing which colours to use. The inclusion of colour in a hazard map can be of great benefit, but only if done in a way that does not detract from the efficacy of the map.

2.3.4 Geographical information

Regardless of the aesthetics of the map, or how much information it contains, for a map to be of use the user must be able to locate himself/herself or another location of interest, other important locations, and the location of the hazard in relation to the rest. In order for the user to remain safe and avoid danger, he or she must know where the hazard is. Alexander (2004) explains the role that these geographical features play when he writes that “geographical knowledge, and the operational decisions that stem from it, will depend on instantaneous perception of space and place.” Alexander goes on to say that some of the most common things people use as a reference are roads, rivers, buildings, etc. We use these geographical features that we are familiar with as a frame of reference for new locations. Kurowski et al. (2011) write about geographical information in tsunami hazard maps and list several different types of geographical information such as road networks (which they highlight due to the need of knowing which roads are dangerous or closed in the case of an evacuation), assembly area, and infrastructure. This information is necessary for users to understand where the hazard is in relation to them, and where safe locations are.

2.4 Uncertainty

Now that the key elements of a hazard map have been established this review will look at the process of creating a map, or what areas must be considered during the creation. Hazard maps are based off of models and/or historical data, and with each there will be a degree of uncertainty associated with it, as historical databases may not be complete. Also, models are a simplification of things in the real world (Brown and Innocent 2012). An aspect of hazard maps which it discussed frequently but does not have unanimous support among researchers is being open and transparent about the uncertainty in the map (e.g. how certain the initial data put into the model is, how accurate the output is). Some researchers believe that the amount and type of uncertainty should be made clear in every map, while others are not so certain (Doyle et al. 2011; Spiegelhalter, Pearson, and Short 2011). Two of the main reasons researchers feel that the uncertainty should be made clear is that it allows the user to make a more informed decision, and that admitting uncertainty fosters trust (Kootval 2008). The WMO states that "surveys show that uncertainty information does not undermine people's confidence in the service – on the contrary, it reassures people that they are being dealt with honestly, and gives them confidence that the services is being provided objectively and scientifically" (Kootval 2008). Explaining how knowing the uncertainty involved in the map can lead to better decisions by professionals, McCarthy et al. (2007) write that "together with the level of certainty associated with the prediction, the additional error information... is crucial for the [Environment] Agency professionals at the [floodplain] Barrier. This is because it avoids Barrier operators compounding the error with their own estimates of wider decision uncertainty."

However, other researchers argue it is not beneficial to be completely transparent about the uncertainty in the map. "There is much discourse in the psychological literature as to whether revealing the uncertainties associated with a risk assessment will strengthen or decrease trust [which the audience places] in a risk assessor and their message" (Doyle et al. 2011). Doyle et al. explain that on the one hand, admitting uncertainty builds trust and enhances the message provider's credibility; however, there are some studies which suggest that it can decrease the credibility of the message provider and people's trust in his/her message. Johnson and Slovic (1995, 1998) conducted a range of tests with local residents of an area and found that around 1/3 of the respondents (who would be considered lay people, or non-experts) deemed the pertinent agency less competent when they included uncertainty in the discussion. They suggest that this may be due to the idea that "if science is deemed certain, uncertain risk estimates must come from incompetent scientists" (Johnson and Slovic 1995). Spiegelhalter, Pearson, and Short (2011) support this idea and state that there is no consensus on the benefit of communicating uncertainty, and while some people may welcome the acknowledgement, others may become confused or even suspicious. Doyle et al. (2011) also put forth "that the provision of uncertainty can allow people to justify inaction or their own agenda..." Despite these misgivings, the number of researchers that support conveying uncertainty far outweigh the numbers of those who oppose it. However, it should be remembered that the extent of the inclusion of uncertainty in a map should depend on who the intended audience is. This idea will be discussed further later in this thesis.

Deciding to convey uncertainty is only the first step. Once this decision has been made, the creator of a hazard map must then decide how to convey it, which is a complicated task. As Novak, Bright, and Brennan (2008) point out: “The potential socioeconomic advantage of providing uncertainty information over traditional deterministic [weather] forecasts has been demonstrated... however, identifying effective methods of communicating forecast uncertainty has been challenging.” Severtson and Myers (2013) caution that even though maps usually have a disclaimer about the proper way to use the map, there needs to be a way to convey uncertainty within the map itself as most people don’t read the disclaimers. They also state that in general visual images denote more certainty than text- and/or number-based messages, such as confidence intervals (Brown and Innocent 2012), and recommend that to combat this bias map creators should specifically include map features which communicate uncertainty.

Severtson and Myers explain the two basic ways of conveying uncertainty: one is by using extrinsic methods which add symbols to the map to denote certainty, and the other is by using intrinsic methods which change the appearance of the information itself to denote certainty. Some commonly suggested intrinsic methods are varying the colour hue, colour value, and texture according to certainty (MacEachren et al. 2005; Severtson and Myers 2013; Spiegelhalter, Pearson, and Short 2011). Severtson and Myers (2013) make sure to point out that if a map is using colour to depict certainty, special care should be taken that not too many shades are used as research has shown seven to be the maximum number of shades of a single colour the average person can accurately differentiate. One option for communicating uncertainty when contours are being used is to make the contours “fuzzy” or out of focus (MacEachren et al. 2005; Severtson and Myers 2013). An example of incorporating uncertainty into a forecast is hurricane forecast maps (Figure 2.2). Starting in 2004, the majority of hurricane forecast maps created by the National Hurricane Center in the USA included the “cone of uncertainty” as a central method of communicating the hazard and its associated uncertainty (Broad et al. 2007). The “cone of uncertainty” is an amalgamation of all of the most likely paths that the storm could take according to models which they have run. In this way the forecast helps the user incorporate the uncertainty into their decision-making by clearly marking a range of possible outcomes (Broad et al. 2007; Brown and Innocent 2012; Kootval 2008; and Regnier 2008).

One area of concern may be that adding a depiction of uncertainty to the map will make it more complex which will result in a longer time required for comprehension (Leitner and Buttenfield 2000). Leitner and Buttenfield (2000) and MacEachren et al. (2005) conducted studies in which one of the topics evaluated was how the inclusion of uncertainty-related information affected interpretation of hazard maps. Both groups found that the inclusion of the information did not hinder comprehension speed and helped the participants make more correct choices. MacEachren et al. (2005) write that "response times were similar with and without uncertainty representation, from which the authors conclude that representation of uncertainty acts to clarify mapped information rather than to make the map cluttered or complex." Leitner and Buttenfield (2000) agree and write that "it would seem that map certainty is understood as clarification rather than adding complexity to a map display."

Along with displaying the uncertainty, it is also important to clearly explain where the uncertainty comes from. "Specify the sources of uncertainty, such as whether these arise from disagreements among specialists, absence of data, or imprecise data. Distinguishing between uncertainty arising from disagreement and uncertainty arising from imprecise but consensual assessment is especially important" (Smithson 2011). To make full use of the information regarding uncertainty, it helps for the user to understand why there is uncertainty so that they know how much credence to give it in their decision process. Explaining where the uncertainty comes from is especially important when it cannot be distilled down to specific numbers (e.g. confidence intervals). Brown and Innocent (2012) argue that "it is misleading to quantify uncertainty that cannot be quantified – in these cases there is an even greater need to talk equally clearly about what researchers do not know as what they do.” Fisher (1991) states that a central objective for risk communicators is to “help the audience understand the science behind the risk assessment.” Most researchers agree that uncertainty and its sources should be made clear in a hazard map, and some suggest that it is even more important to discuss the sources of uncertainty when the level of uncertainty cannot be quantified.

2.5 Motivating people

Regarding hazard maps, Monmonier (1997) says that “persuasion is their prime role, after all, and if they fail to convince or at least command attention, they miss their most important target.” However, many people are not motivated to take any particular action in response to a hazard warning unless they are able to see how they personally will be affected (as will be shown in the following examples). Paton et al. (2001) studied a community in New Zealand exposed to volcanic hazards, finding that people’s perception of risks were influenced by how the hazard affected them personally and economically, rather than the actual level of volcanic activity. They state that “this conclusion has implications for risk communication. For examples, it suggests that message content should target the threat(s) perceived as salient by the community.” They go on to provide an example using an ashfall event and suggest that in that case, information regarding ash would have a greater impact if it was presented in a way that showed how it would impact economic activity, and if the suggested responses were presented in a manner which showed how they would protect personal interests. Gregg et al. (2004) support this idea and state that the widely held idea that simply increasing a person’s awareness of a hazard will cause them to be more prepared for it “is not always justified and has fallen well below expectations”. Speaking on the psychological side of decision making, Slovic et al. (2005) write that “feelings of dread... [are] the major determiner of public perception and acceptance of risk for a wide range of hazards”. It is not enough to inform people about the hazard. They must see how they will be affected by it.

2.6 Participation in the process

There are two reasons presented in the literature for incorporating audience feedback when creating a hazard map. One reason is to build trust between the organisation issuing the map and the people using it. If the audience recognizes that their input and preferences were taken into account during the creation of the map they will be more open to using it and following recommendations based upon it. Slovic (1997) wrote that there needed to be a new approach to “risk science”, an approach “that focuses upon introducing more public participation into both risk assessment and risk decision-making in order to... increase the legitimacy and public acceptance of the resulting decisions”. Many researchers agree with this viewpoint, as evidenced by the increasing number of scientists calling for more audience participation.

The other reason for incorporating audience feedback into the creation of the hazard map is to ensure that it is as applicable to the user as possible (Fischoff 1995; Newhall 2000). There is no reason to produce a hazard map if it does not convey any information that the user needs. As Broad et al. (2007) describe it, “what to include and not include should in part be a function of who the intended audience is and their ability to handle different sorts of information”. They go on to explain that when developing something such as a forecast map, the creator should consider who the intended audience is, what their needs are, how relevant the information is, and whether or not there is enough detail for people to assess the risk themselves. The best way to find the answer to these questions is to directly ask them. As Fisher explains, the most effective way to communicate risk is to empower the audience. This is accomplished making the relationship one of two-way dialogue, finding out what their concerns are, including those concerns in the assessment, and helping the audience interpret the results (Fisher 1991). Nave et al. (2010) point out that it is important to seek audience feedback even on finer elements such as what colours are used, as different colours may have different inherent connotations to different groups. For example, if red is used on a tsunami hazard map a member of the general public could interpret the red to mean danger, whereas a cartographer could interpret the red to mean raised elevation and thus safety from the tsunami. As Haynes, Barclay, and Pidgeon (2007) suggest, even though one single map cannot be created which meets everyone's needs, "with input and feedback... a single more optimum map can be produced which helps the majority of potential users." However, an opposing viewpoint present in the literature was that "one size does not fit all." Broad et al. (2007) argue that different people and agencies will need different information in order to most effectively respond to the hazard. They state that "there is no perfect "one size fits all" image. No one presentation format or piece of information will be interpreted in the same way by all people". Some consideration should be given to creating specialised maps if multiple agencies will be relying on the hazard maps to respond to a natural hazard.

2.7 Summary

Along with the benefits of using hazard maps, there is a large amount of consensus around what are the important features of a hazard map. Some of the topics listed by Drabek (1999) as critical to a hazard map have been mentioned numerous times in the literature, but others have not. Topics such as the probability of the event (uncertainty) and the inclusion of geographical information have been extensively covered in the literature. Though their benefit can be seen and appreciated, not many papers were found to include the topic of the timing of the event, nor the topic of including what specific actions should be taken. Other topics are inherently answered by nature of using a hazard map, such as what hazard is threatening and what exact region is affected. Summarising all of the literature, it is found that the critical features for a hazard map are: overall simplicity, the base map, map scale, the use of colour, geographical information, and the incorporation of uncertainty. The literature suggests that for a hazard map to be effective it must satisfy the requirements of these features. As such, special attention will be paid to these features through the rest of this thesis. Other important aspects of producing a hazard map which have been addressed are showing people how they will be affected, the importance of taking audience feedback into account, and the idea that one size does not fit all.

Now that the key features and aspects of a hazard map have been identified, the remainder of this thesis will be spent putting this information to the test. As Nave et al. state, hazard maps are important, but the current version needs to be improved (Nave et al. 2010). The purpose of this research is to fill that need and improve the quality of hazard maps. The literature review was used to identify what the key features of a short-term hazard map are, and the process which needs to be taken to create the map. Those results were then applied to short-term hazards map, as will be shown in the next chapter.

Chapter 3 Methodology

3.1 Overview

This chapter describes the methodology used in this thesis study. A mixed-methods approach was used to address the research questions. This is summarized in this overview section and then explained in detail in the remainder of the chapter. For information regarding how ethics standards were observed see Appendices A, B, and C.

1. A literature review was undertaken to review and summarise existing knowledge in the field of hazard and risk maps, natural hazard warnings and communication theory. This was used to build a knowledge base of what is 'best practice' for providing warning of natural hazards, which was then used to inform the subsequent data collection methods. (Chapter 2)
2. Interviews were held with scientists from GNS Science (the New Zealand national agency responsible for issuing volcanic warnings through the GeoNet programme) to investigate how and why the current ash fall warnings have been developed, designed and executed. (Section 3.2)
3. Ashfall forecast maps were developed based on these first two methodological steps.
4. Interviews were held with key selected endusers from the ashfall forecast map's intended audience to identify in high resolution what their requirements were from a GeoNet ash fall hazard warning map. (Section 3.3)
5. The ashfall forecast maps that were created in step 3 were trialled with these endusers to elicit critical feedback, and changes to the map design were made accordingly.
6. A survey was developed for distribution to the intended audience of the GeoNet ash fall hazard warning maps (Section 3.4). The survey was distributed to a broad range of organizations and individuals (although it excluded the general public) to collect data on the requirements different end users had from GeoNet ash fall warnings maps.

The updated ashfall forecast maps were included and the participants were asked to interpret the maps to answer a series of questions and critique the maps in their professional roles.

7. The map design was once again updated according to the results of the survey to produce the optimal map.

The creation process for the ashfall forecast maps was an iterative one and required audience participation. Both provider and enduser must have the opportunity to provide input for the map to be as effective as possible. It would be extremely difficult to gather all of the preferences from all of the scientists and stakeholders simultaneously and then try to design a map that satisfies all of the requirements. Therefore, the map was enhanced and improved in stages (Figure 3.1). After each round of interviews and after the completion of the survey, the information gathered was analysed and used to inform the design of the next iteration map accordingly.

To understand the reasons for choosing the methodology used in this research, one must first understand the setting in which it was conducted. New Zealand has active volcanoes which produce ashfall. Ashfall has the potential to cause a large amount of damage. Therefore an ashfall forecast must be rapidly created following an eruption to help people and organisations take steps to minimize the impact of the ashfall. The forecast tells where

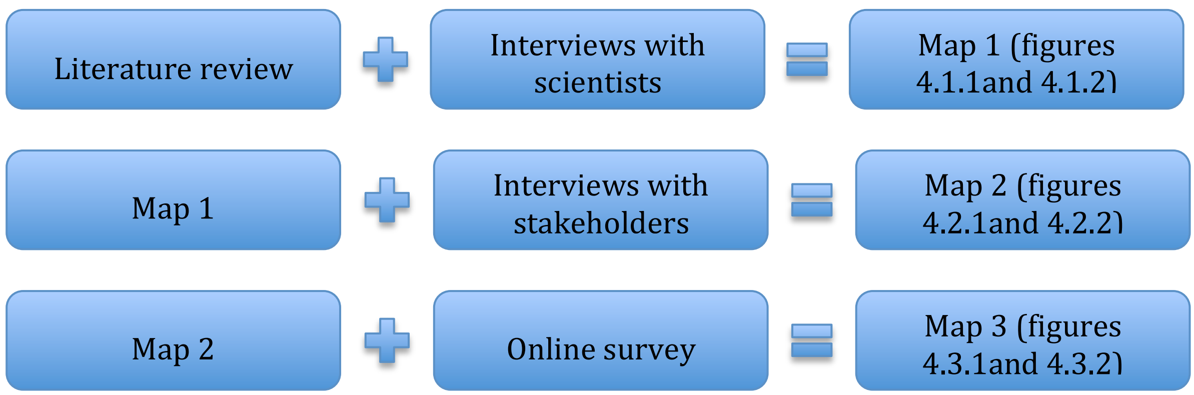


Figure 3.1: A diagram showing what information went into each version of the map and how previous information was incorporated.

the ash is expected to be deposited so that people and organisations in the affected area can prepare themselves. GNS is the agency that has been given the mandate to create these warnings for New Zealand, and they must communicate the hazard as effectively as possible to the endusers. It has been shown that a forecast map is the most effective way to do this. The intended audience, or endusers, for the forecast map are any organisations that will use it to inform their decisions, such as local and national Civil Defence offices, local and national Ministry of Health offices, infrastructure and lifeline companies such as Vector Ltd. and Watercare Ltd., and local businesses. Members of the public may also use this map to inform their actions, but they are not considered the target population for this research, as they will be receiving direction from government agencies.

So as to include input from the provider and the enduser, scientists and stakeholders were interviewed as well as invited to participate in the survey. The purpose of both conducting interviews and distributing a survey was to ensure that detailed information was gathered, and that the information represented the general opinion of the group as a whole. Also, this allowed the scientists and stakeholders who are involved with the maps to be the ones who indirectly determined the topics for which quantitative data was gathered. The interviews gathered high-resolution data from a small group, and the survey was a low-resolution check of the information by a large group.

3.2 Interviews with GNS scientists

It is necessary for the providers of the forecast map to have a say in how it is designed. If the map were to be created based solely on the opinions of the endusers it might not include all of the information that they need to respond effectively (sometimes a person does not know what they need until they see it, or until they are actually faced with the emergency). Alternatively, it may be designed in a way which, while aesthetically more pleasing, does not communicate the information as effectively, or the end users might request so much information and analysis that it is no longer feasible to produce such a map. To this end, interviews were first conducted with six members of the volcanological team at GNS Science who are either involved with or have contributed to the production of ashfall forecast maps. The scientists interviewed are not identified in this study, but examples of some of their positions are (generally): team management, hazard modeller, volcano surveillance, and volcano geophysicist. The interviewees were chosen from a variety of positions within the volcanological team to ensure that different viewpoints are included.

The aim of the interviews was to obtain the professional judgments from individuals acting in their professional capacity. As such, interviewees were able to give differing opinions on topics without concern of offending others because it was based on what they had experienced in their professional capacity and not personal opinion. Questions in individual interviews were tailored so as to gather the most pertinent information based on interviewees' backgrounds and roles. This is also why the interviews were conducted individually rather than as a group, so that each person had to opportunity to speak in-depth to their specific role and experiences. Individual interviews also helped ensure that one interviewee's thoughts and/or answers would not be influenced by another's, and that each person could take the amount of time they wanted to answer a question without concern for taking time away from someone else. Open-ended questions were used to allow the interviewees to freely convey the knowledge that they had without being restricted to set options or only ideas that the researcher could think of. The interviews were held in the offices of the interviewees so that they would be in a comfortable, familiar surrounding.

The questions were developed with the help of the supervision team and based on information gathered from the literature review. The questions asked can be found in Appendix D. The interviewees were provided with a copy of the questions in the email inviting them to participate so that they would have time to contemplate the questions and make any preparations they felt were necessary. Notes were taken during the interview, and the interviews were audio-recorded to allow for the interview to be revisited and further notes taken, however no transcript of the recording was created. All of the data is stored on password-protected computers and servers to which only the research team has access.

After the interviews were completed, the responses were analysed on a topic-by-topic basis. Each interview question was considered a stand-alone item (except for several which specifically reference another question), and there was not meant to be a connection between subsequent answers nor a common idea influencing all of the responses. It is possible that answers to previous questions influenced later ones, but that was not the intent of the interview. Therefore, it was decided to not transcribe the interviews and code all of the responses to look for such connections. If such connections do exist, they are not the focus of this research. However, due to the interconnected nature of hazard mapping, specific topics would be mentioned in the responses to multiple questions. The analysis method that was found to be most effective was thematic analysis (Braun and Clarke 2008). This method consists of selecting a specific topic or idea and reading through the notes from all of the interviews looking for when the topic or idea appears (Vaismoradi, Turunen, and Bondas 2013). Each time the topic-of-interest was mentioned, the corresponding audio segment was reviewed and further notes were taken. In this way the analysis did not depend on memory recall and notes taken during the interview. All of the information gathered on each specific topic throughout all of the interviews was collated, allowing for a general theme or themes to be distilled.

3.3 Interviews with stakeholders

Input from the map's endusers is also critical in effective map design. A map based solely on the opinions of the scientists providing it might not include all of the information that the endusers want or feel is important, or might display it in a way difficult for a nonexpert to understand. Therefore, the second round of interviews was conducted with people from various stakeholder organisations. A range of potential interviewees was chosen to represent multiple areas (government, infrastructure, business, etc.), as different areas may have different preferences and/or requirements. All of the potential interviewees were sent an email inviting them to participate in this research, and the seven that responded and were willing were interviewed. The interviewees are not being identified in this study, but the agencies they represent are: Watercare Ltd., Bay of Plenty Regional Council, Auckland Council Civil Defence and Emergency Management, Auckland Airport, and the Auckland Engineering Lifelines Group.

As with the interviews with the scientists, the aim of these interviews was to obtain an understanding of operational information needs from people acting in a professional capacity. Since not all interviewees had personal experience responding to a natural hazard in their current role, they were not able to look back at what had worked in the past and what information was needed, as others were. In these cases the interviewees were asked to answer to the best of their ability based upon their own thoughts and opinions as well as any training and/or exercises they had participated in. The identity of the stakeholders interviewed and their responses were not revealed to the other interviewees, which allowed them to express themselves freely. All of the stakeholders received the same questions as each other to discern where their opinions and preferences agreed and differed. The questions used were developed with the help of the supervision team and based on information gained from the literature review and the interviews with the scientists. The stakeholders were also asked to participate in a brief thought exercise in which they were to imagine themselves at work when an eruption occurred. They were then provided with the maps one at a time and asked to mentally go through how they would utilize the map in their response. This approach encouraged the stakeholders to critique the maps based on their efficacy rather than aesthetics. The questions asked can be found in Appendix E. Due to the limits of schedules and the level of detail which some of the interviewees went into when answering questions, not all of the interviewees were able to respond to all of the questions prepared for them. As this was an unforeseen complication, the questions were not prioritised beforehand and therefore the questions skipped were chosen solely based on their position in the list. As with the scientists, the stakeholders received a copy of the questions with their invitation so that they would have time to prepare.

Four of the stakeholders were interviewed separately in one-on-one interviews in their offices, for the same reasons as explained for the scientists. The remaining three stakeholders were interviewed as a group because they all hold the same position at the same institution (one is the principal for the position and the other two are alternates for when the first is not available). Since they hold the same position it was reasoned that their needs would be the same, and that it would be to their benefit rather than detriment to interview jointly because they would complement each other (one might remember something that another forgot). The interviews with the stakeholders were also audio-recorded for note-taking purposes, with no transcript written. The data is protected in the same manner as the data from the interviews with the scientists.

The responses to the stakeholder interviews were analysed in the same manner as the responses to the GNS interviews, and for the same reasons. Each question was intended to be answered independently (except when specifically noted otherwise), and searching underlying themes is not a focus of this research. Selecting one topic at a time and gathering all of the information provided about it showed how stakeholders did or did not agree with each other concerning the topic.

3.4 The survey

The final step in the information gathering process was the survey, the purpose of which was to verify the information gathered in the interviews with a larger number of people. The interview information was incorporated into the map design (Section 3.4) and then the map was presented in the survey to determine if the scientists and stakeholders in general agreed with the changes that had been made.

At the beginning of the survey the participants were asked what information regarding a volcanic eruption they would need in order to respond effectively to the event. This was done to see what the endusers' initial opinions were before being influenced by viewing maps. Following this, they were asked to critique a GNS-produced map. Next, the two maps which were created for this research were presented alongside a GNS-produced map (which showed the same eruption as one of the newly created maps) and the participants were asked identical questions about all three. The maps were presented in this manner to ascertain the participants' thoughts concerning the changes. Because the same questions were asked about the GNS-produced map and the new maps, the level of approval that the attributes received on each map can be directly compared to ensure that the changes made are generally supported by the group as a whole. If an attribute of the map received more support on the new maps than on the currently used map, it was interpreted that this change was a positive one that is supported by the scientists and stakeholders. Conversely, if an attribute received less support on the new map than on the currently used map, it was interpreted that this change is not supported by the scientists and stakeholders and must be re-evaluated. Due to the need to keep the list identical for all maps despite the addition and removal of some attributes, some of the attributes listed did not appear on the map being critiqued.

3.4.1 Survey distribution and analysis

Since the purpose of the survey was to verify the opinions of the community as a whole, it was important to get as many people as possible to participate in it; the more people that participated the more representative the results. The most effective way to maximize the reach of the survey was to use the "snowball" method. The email inviting people to participate was first sent to personal contacts formed during courses and conferences, personal contacts of members of the supervision team, and any pertinent people for whom contact details could be found via the internet. These initial recipients came from all applicable sectors (e.g. scientists, CDEM, utilities). Within the text of the email participants were to forward the message on to anyone he/she thought might be a good candidate for participation. Limited contacts could be found by searching information publicly available on the websites of the different agencies, therefore it was more effective to allow members of the community to use their already established channels of communication to expand the reach of the survey. A copy of the survey questions can be found in Appendix F.

Since the survey had a different purpose than the interviews, the method of analysis was different as well: the scores for each question were evaluated (each response option was given a numerical value, ascending in correlation with the level of support expressed; see Figure 3.4.1 for an example of a survey question). If an attribute received a high mean score

Please critique each aspect of the map

	I dislike it very much	I am indifferent about it	I like it very much
Use of colour			
Ski fields			
Names of towns and cities			
Locations of towns and cities			
Inset map			
Scale bar			

Figure 3.4.1: An example of a survey question. For the analysis stage the different levels of support were assigned ascending numbers (I dislike it very much = 1, I am indifferent about it = 2, I like it very much = 3). The mean score for each attribute was then evaluated to determine the level of support that attribute received.

it meant that the participants supported it, and if an attribute had a low mean score it meant that they did not. All of the attributes which received an exceptionally low mean score were understood to have received little support from the audience, and therefore were evaluated to determine if they should be modified. The results were also cross-tabulated according to the profession of the respondent (asked at the beginning of the survey) to determine if there was a noticeable difference in level of support for an attribute between scientists and stakeholders. The written responses were reviewed to determine if there was an idea or opinion which did not come up in the interviews (and thus was not present in the survey) but received a high level of support in the survey.

3.5 Developing an 'optimal' map

The goal of this research is to create a forecast map which is as effective as possible for as many stakeholders as possible. The best way to do this is to gather and incorporate information from both the scientists producing the forecast map and the stakeholders using it. As has been described, the creation process for the ashfall forecast maps was an iterative one. After each analysis phase (conducted after each round of interviews and after the completion of the survey), the map design was updated to reflect the new information that had been gathered. When the analyses resulted in the recommendation to change an element of the map, all of the information gathered up to that point concerning the element was reviewed. The amount of support for and against the element was considered, as well as the sources of the information (for example, if the element were a solely aesthetic one, the preferences of the stakeholders would carry more weight than those of the scientists because the stakeholders are the ones that use the map). After all of the information was considered, a decision was reached concerning how the element would appear (or possibly not appear at all) in the next version of the map. In this way the map was continually evolving and improving as new information was gathered, but the first pieces of information gathered had the same amount of influence as the last.

The iterative process was also effective because it allowed the participants to look at a map and critique it rather than requiring them to imagine and describe their ideal map. Participants were able to study the previous version of the map and note elements that they felt were not effective. This would not have been possible if no map design was created until after all of the information had been gathered. In addition, with a new version of the map being created after each round of analyses, the survey was able to effectively evaluate whether or not the information gathered in the interviews adequately represented the views of the community at large. Since each version of the map design incorporated all of the information gathered up to that point, the maps presented in the survey were the direct result of the interviews with the scientists and stakeholders.

3.6 Summary

The forecast map was developed iteratively. This development process allowed subsequent participants to critique the suggestions of previous ones, helping to eliminate any ideas that were good in theory but not in practice. The combination of interviews and the survey was effective because it allowed for the gathering of high-resolution data from a small group and then that information was verified by a collection of low-resolution data from a large group. This process allowed everyone's voice to be heard while still keeping the creation process manageable.

Chapter 4 Results

In this chapter the results of the research will be presented. As outlined in Chapter 3, the process for this research was an iterative one, with the map design updated after each stage of information gathering. As such, the focus of this chapter will be on how new information influenced the design, with the data gathered being used to support the changes. Each version of the map is presented, and the changes that were made to it are discussed and justified. The creation of an effective hazard map is a process (see Chapter 2). This chapter reflects that process.

Differing opinions were sometimes found during the information gathering, and a selection had to be made. These decisions were made in accordance with the level of support each option received as well as which option would be most effective for this specific map, as determined by the researcher. It must be kept in mind that the "best" option will differ according to the aims of the map being created (e.g. a hazard map for a small village located on the side of a volcano will require a different design and content than an ashfall hazard map for the North Island of New Zealand). As a point of reference, Figure 1.1 shows a current-generation GNS-produced map of a small volcanic eruption. For a brief summary of the results see Table 4.4, located at the end of this chapter.

4.1 Literature review and interviews with GNS scientists.

The first map was designed from the results of the literature review and the interviews with members of the volcanological team at GNS (see Chapter 3). The recommendations from the scientists were compared to the findings of the literature review (see Section 3.2). When there was disagreement on a topic (be it between scientists and the literature, between different scientists, or between different sources in the literature) and significant support or reasoning could not be found for one opinion over the other, both options were included. In these cases, the two options were placed onto separate maps. Therefore, two versions of a short-term hazard ashfall map which showed the same eruption were created and presented in the next round of interviews. Those topics will be noted here, but the results of which option was selected will be addressed in the subsequent section. The points of interest for the first round of maps that will be addressed are: the use of colour, the scale of the map, additional information page, style of base map, geographical information, inset map, and the inclusion of uncertainty. Each topic will be addressed individually.

4.1.1 Colour

Colour was included due to the support for it in the literature and the interviews. Three out of the five scientists at GNS who were asked about the use of colour on the map supported it. One interviewee who is opposed to using colour argued that the alert is still sent by fax machine, which cannot convey colour, and that not everyone has access to a colour printer. However, very few people still use fax machines. Regarding GNS specifically, one interviewee who is in a supervisory role stated that "traditionally the [volcanic alert] bulletin was sent out by a combination of fax and email, and we're going away from fax, which is good because nobody really uses fax anymore. Probably within the next month or so we will actually switch off the faxes." One of the scientists at GNS also noted that the map can be designed so that the colours used will still convey the same information when printed from a black and white printer. This can be further investigated if enough of the intended audience is expected to not have access to a colour printer for it to be a concern. Due to this option, the scientists at GNS supporting the inclusion of colour, and available literature, colour was included in this map.

The colours used were chosen based upon: having more than two colours present (if only two were used it would have the same resolution as a black and white image), as recommended by two interviewees at GNS; using colours which would not be misinterpreted by those who are colour blind (e.g. not placing red and green next to one another in the scale), which is a consideration mentioned by an interviewee at GNS; and avoiding the use of colours which have certain affective responses (such as red for danger), as counselled in the literature (Slovic et al. 2005). In conjunction with the last idea, an interviewee at GNS argued that if a traditional red to green scale were to be used the audience might immediately associate the green areas with safety. This is not desirable as every region marked on the map will receive some amount of ash, so no region that is marked should be considered a “safe zone”.

4.1.2 Scale

No definitive determination could be made regarding what scale the map should be set to. The literature supports using a scale which is appropriate for the size of the event, since the details of a small event would be hard to see on a small-scale map (e.g. 1:10,000) and a large-scale map (e.g. 1:100) would not capture all of the information of a large event. However, two of the interviewees at GNS argued that the map should be left at a small scale for all events because the model itself is not certain enough to provide fine details. They feel that having the map close up on a small event would convey a greater sense of certainty than actually exists in the data, which would lead to the endusers using the map inappropriately. Because of this difference of opinion both options were presented to the endusers in the next round of interviews. Figure 4.1.1 shows the small-scale option and Figure 4.1.2 shows the large-scale option.

4.1.3 Additional information

The additional information (information outside of the map itself) was included due to four of the interviewees recommending an additional sheet of information, and the need to keep the map itself as clutter-free as possible (as discussed in Chapter 2). There is much information which needs to be communicated, but too much information packed into a graphic will make it confusing. These interviewees suggested that the best way to convey the information while avoiding cognitive overload is to create an informational sheet to accompany the map. One interviewee warned that no critical information should be placed solely on the informational sheet as it is common for a secondary, text-heavy sheet to be overlooked or intentionally ignored. Due to these suggestions the map was designed to contain all of the most pertinent information (each map creator should communicate with their audience to determine what is the most pertinent information to them), and the additional information page would contain the same information presented in a text-based manner as well as information deemed to be of secondary importance by the issuing organisation. With the information presented in this manner, if the second sheet is lost, the user still has all of the fundamental information. Also, if a user only has a few minutes to make a decision they can choose to ignore the extra information and focus solely on the map.

4.1.4 Base Map

The style of base map was chosen due to the results of both the literature and the interviews. As explained in Chapter 2, the base map should be whatever style is most effective for the situation and most appropriate for the intended audience. In this setting, it cannot be guaranteed that all, or even the majority, of the endusers are familiar with contour maps, therefore they cannot be used. All of the interviewees supported the choice of a simple plan view map and two of them stated that they have already found success with this style (as it is the style used for the current short-term ashfall forecast map produced by GNS, see Figure 1.1). Haynes, Barclay, and Pidgeon (2007) found the general public to be very proficient with an aerial photograph, but when modelling far-reaching hazards such as ashfall there is the potential for the map to be of a small enough scale that aerial photography is no longer a viable option. Due to these reasons, a simple plan view map was chosen.

4.1.5 Geographical information

As mentioned before, it is important for the map to remain clutter-free, however users need geographical markers present to orient themselves and put the hazard into a frame of reference (see Section 2.3.4). Alexander (2004) lists roads, rivers, and buildings as some of the most common things people use as geographical markers. Two of the interviewees at GNS supported the idea of marking towns/cities and state highways, as they feel that towns/cities alone are not enough geographical information. However, two others felt that only the towns/cities should be displayed. The decision to include the state highways was based upon the support in the literature concerning providing an adequate amount of familiar geographical information. To continue the aim of avoiding too much information and clutter, no state highway numbers were displayed and the towns/cities were presented in one of two manners. If a town/city is likely to receive ashfall, it is marked with a red circle and the name is provided. If a town/city on the map is not likely to receive ashfall it is marked with only a blue circle. In this manner the locations of all of the towns and cities are marked, but only those likely to be affected are prominent. Two local ski fields were also included in the maps as they were considered to be important geographical markers during the winter when there is a large amount of people there. Choosing whether or not to include the ski fields dependent on the time of year would be extra work for the duty officer issuing the forecast map. Since the duty officer does not have time to spare when issuing a forecast, it was decided that the markings for the ski fields would be shown at all times. However, if the decision to add or remove the symbols can be automated then it may be preferable that they only be shown in winter when it is likely for many people to be there.

4.1.6 Inset map

The inset map is included on one of the maps due to comments in the interviews. Two interviewees raised the concern that if the map is set to a large scale in order to better depict a small eruption, then users not familiar with the location may not be able to place it appropriately in reference to the rest of the island. There was no literature found which addressed this concern. The literature does support using a scale which is appropriate for the size of the event (as discussed earlier), but it also supports including enough geographical information for the user to place the hazard into a frame of reference which they are familiar with (also discussed earlier). Also, no information would be removed from the map to make a space for the inset map, so the only negative aspect of including it would be adding clutter. Due to the concern of some of the scientists and the lack of literature on this topic, the inset map was included on the large-scale map to see how endusers responded to it.

4.1.7 Uncertainty

Both the literature and the interviewees were split in their decision regarding the inclusion of uncertainty in the map, but in both cases there was more support in favour of the inclusion of it. One of the concerns of some of the interviewees regarding including the uncertainty is that due to the nature of the modelling program which GNS uses, there is no way to definitively quantify the amount of uncertainty present in the map (this is not the case for all models). These scientists feel that you cannot include a level of certainty with the map unless you are able to determine a firm, definite number. However, the literature shows that there are ways to convey uncertainty without providing specific levels (see Section 2.4). Three of the scientists interviewed agreed with using visual means to include uncertainty, so that the uncertainty could be represented but not specifically stated.

The uncertainty was included in both a visual manner and a textual manner. Visually, the forecasted ashfall was displayed using graduated colour bands to make the boundaries appear fuzzy or out of focus (MacEachren et al. 2005; Severtson & Myers 2013). Textually, the disclaimer at the bottom of the first sheet states that the model is based on estimations, and in the forecasted ash depths table on the additional information page the values are presented as ranges. One of the interviewees explained that with some research these ranges could be made accurate, even with the uncertainty in the model remaining unknown.

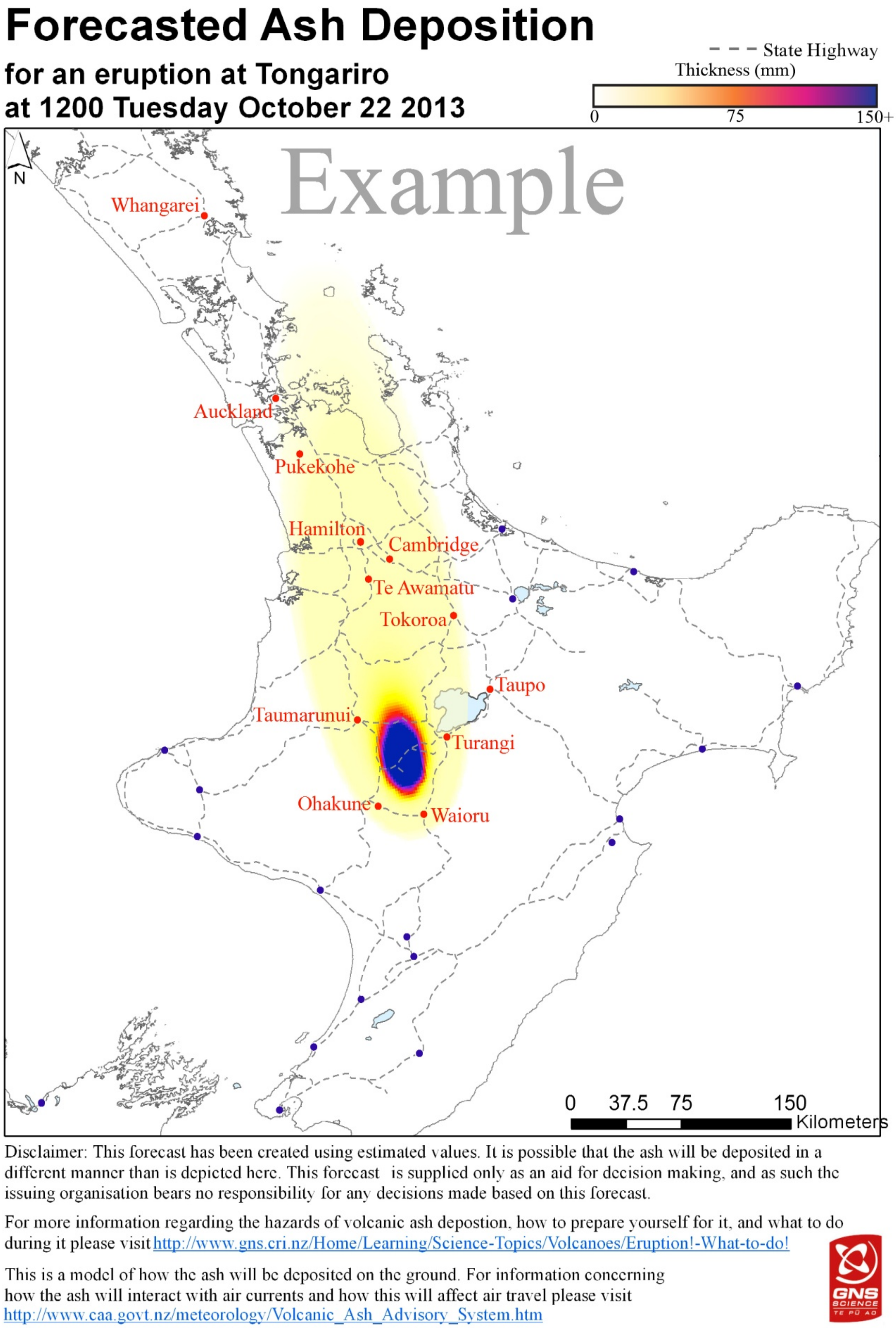


Figure 4.1.1: The first map created showing a hypothetical eruption at Tongariro. This map and the map in Figure 4.1.2 were created using information gathered from a review of the literature and interviews with members of the volcanological team at GNS.

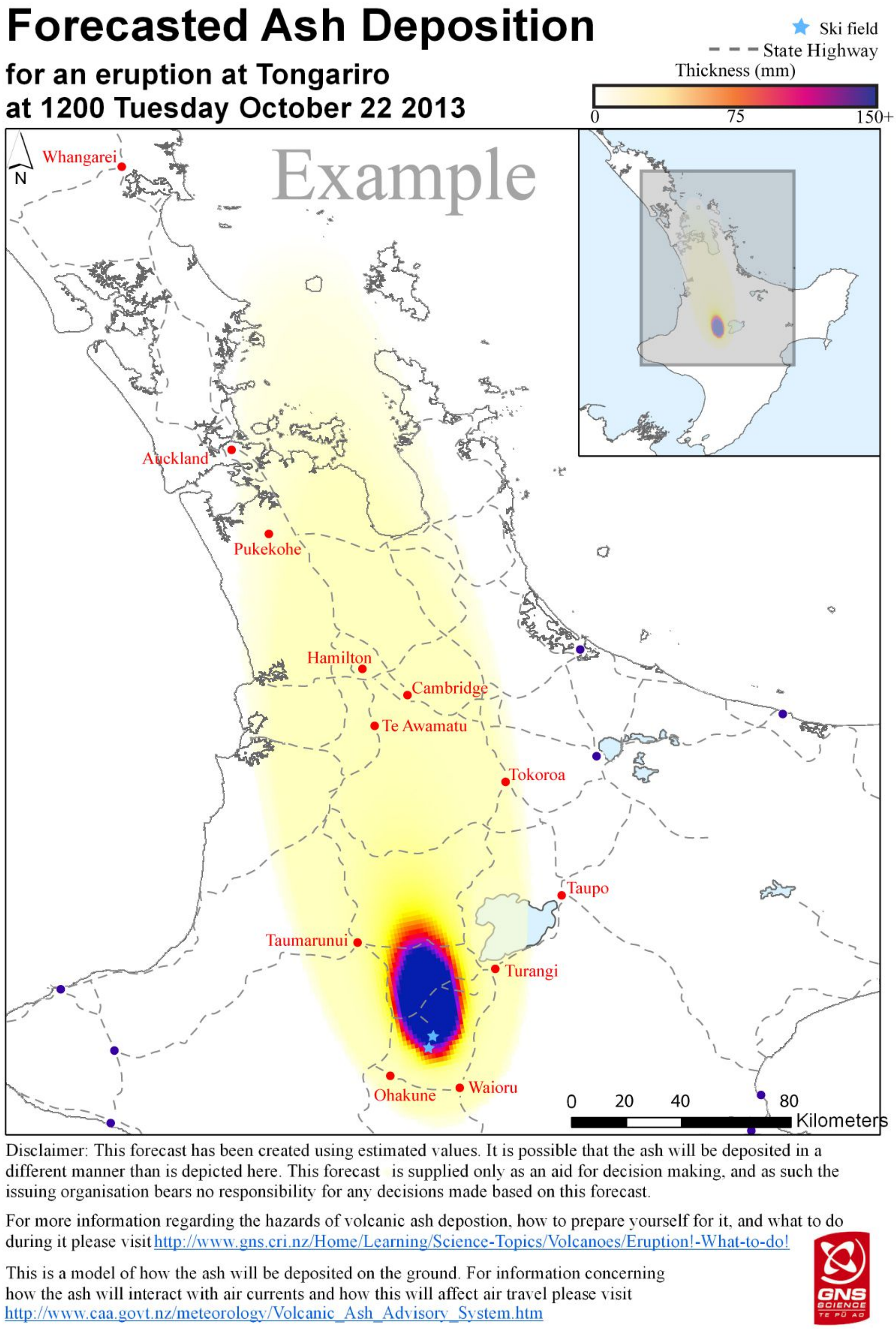


Figure 4.1.2a: The second map created showing a hypothetical eruption at Tongariro. This map and the map in Figure 4.1.1 were created using information gathered from a review of the literature and interviews with members of the volcanological team at GNS.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013
Forecasted ash depths

Town	Depth (mm)
Auckland	5-15
Cambridge	15-45
Hamilton	15-45
Ohakune	15-45
Pukekohe	5-25
Taamarunui	35-75
Taupo	0-2
Te Awamatu	20-50
Tokoroa	5-30
Turangi	25-65
Waioru	20-50
Whangarei	0-2

Wind data

Altitude (km)	Direction blowing	Speed (m/s)
2	N/NW	3
4	S	1
6	N	5
8	N/NW	15
10	N	10
12	NE	4

Critical threshold levels:

Any ash present – Please keep yourself and your animals inside and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs may begin to sag or even collapse under the weight of the ash. It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Example

Figure 4.1.2b: A page of additional information which accompanied the map shown in Figure 4.1.2a.

4.2 Interviews with stakeholders

With the first two versions of the short-term ashfall forecast map created, the next step was to present these maps to pertinent stakeholders. As is shown clearly in the literature, audience participation is a critical step in the creation process of a hazard map. These stakeholder interviews allowed the endusers to voice their preferences and concerns, as well as to be the deciding factor in the undetermined aspects. Interviews were conducted with stakeholders from a variety of organisations (for a detailed list see Chapter 3). The interviewees were asked various questions concerning what information they needed following a volcanic eruption in order to prepare for the deposition of ash, after which they were shown the two maps which had been created and asked to critique them (for a detailed description concerning what was covered in these interviews please see Chapter 3). The responses from these interviews were compared against the information which had been gathered in the literature review and the interviews with scientists at GNS. Where the responses agreed with the previous information no changes were made. Where the responses disagreed with previous information or with an attribute of the map, all of the pertinent information was reviewed, taking into account the source of each piece of information. A decision would be reached with regard to what option is most effective for this specific map, and the map would be left as is, or modified accordingly.

After a final design was decided upon, a second map was created which showed the forecast for a small hypothetical eruption (Figure 4.2.2). This was done so that the effectiveness of each element could be tested in both a large and small eruption scenario. The aspects of the map which received either no comment or general support and therefore remained the same are: the use of colour, geographical information, the style of base map, and the inclusion of uncertainty. Aspects that have been changed and/or added and will thus be discussed are: scale of the map, inset map, additional information, and the inclusion of a time component.

4.2.1 Scale

As stated earlier, some of the scientists as GNS feel that there is too much uncertainty in the map to set it to a larger scale, and fear that if a larger scale were used the endusers would misinterpret this to mean greater certainty. When asked what they understood concerning the uncertainty in the map, all of the interviewees explained that they understand that models have uncertainty inherent in them. They stated they would prefer to receive the most large-scale map possible and then factor the uncertainty into their own decision-making. In support of this idea, two of the three interviewees shown a current-generation GNS-produced map of a small eruption (Figure 1.1) stated that the depiction of the eruption was so small and indistinct that it was of very little value to them. It was too small for them to comfortably base decisions on. The interviews with the stakeholders found that the intended audience understands the uncertainty and does not assume that a larger-scale map means more certainty, contrary to the fears of the scientists (Section 4.1.2). Due to the level of understanding among the stakeholders and their desires for a map of larger scale, the decision was made to have the map set to as large a scale as possible while still showing the full extent of the ashfall, and its surroundings.

4.2.2 Inset map

The stakeholders interviewed were not unanimous in support of the inset map, but there was no clear correlation between the sector the stakeholder represented and their attitude towards it. Some agree that it is a good way to keep the overall location in mind and see what other areas may be affected as well, but others feel that it is unnecessary. However, the reason commonly given for not wanting the inset map was that the main map is already almost at the same scale as the inset map. This is the case because the eruption being forecasted is a large one. One interviewee noted that when forecasting a smaller eruption, there would be a greater difference between the main map and inset map, making the inset map more useful. Since this was the chief argument against the inset map, and there were other interviewees who were in favour of having it, it was decided to keep the inset map. Clearly, whether or not the map should be included depends not only on the preferences of the audience, but also on whether or not the scale of the map makes it practical. For this research the findings are being applied specifically to such maps as GNS produces (such as Figure 1.1), and a critical aspect of the production of short-term ashfall forecast maps by GNS is automation. Having someone decide if the scale is different enough to make the inset map worthwhile for each eruption uses up valuable time and manpower, therefore this process would need to be automated. As the process is not currently automated, a decision had to be made whether to include the inset map on all of them or none of them. The arguments in favour of having an inset map on the large-scale maps are more compelling than the complaints of having an inset map on the small-scale maps, and therefore it was decided to include the inset map.

4.2.3 Additional information

The sheet of additional information was changed in accordance with suggestions from the stakeholders interviewed. All of the interviewees expressed strong support for the inclusion of the informational sheet, but they all had differing suggestions on how it could be improved. Three of the interviewees representing lifeline organisations feel that including the wind data was needless since the data was already factored into the model, and none of their decisions depend on the wind alone. Three of the scientists interviewed also shared this opinion (this was not enough of a consensus among the scientists at GNS to have it removed completely from the first round of maps, which is why the wind data is present in Figure 4.1.2b). The interviewee from Auckland Airport expressed interest in having the wind data included, but did not indicate that it was critical. The support among scientists and stakeholders for removing the wind data, and the lack of stakeholders strongly in support of including it resulted in the removal of the wind data from the informational sheet. The inclusion of a time component was asked for by all of the stakeholders interviewed (two of which mentioned it multiple times), and therefore added (as discussed in the next section, Section 4.2.4).

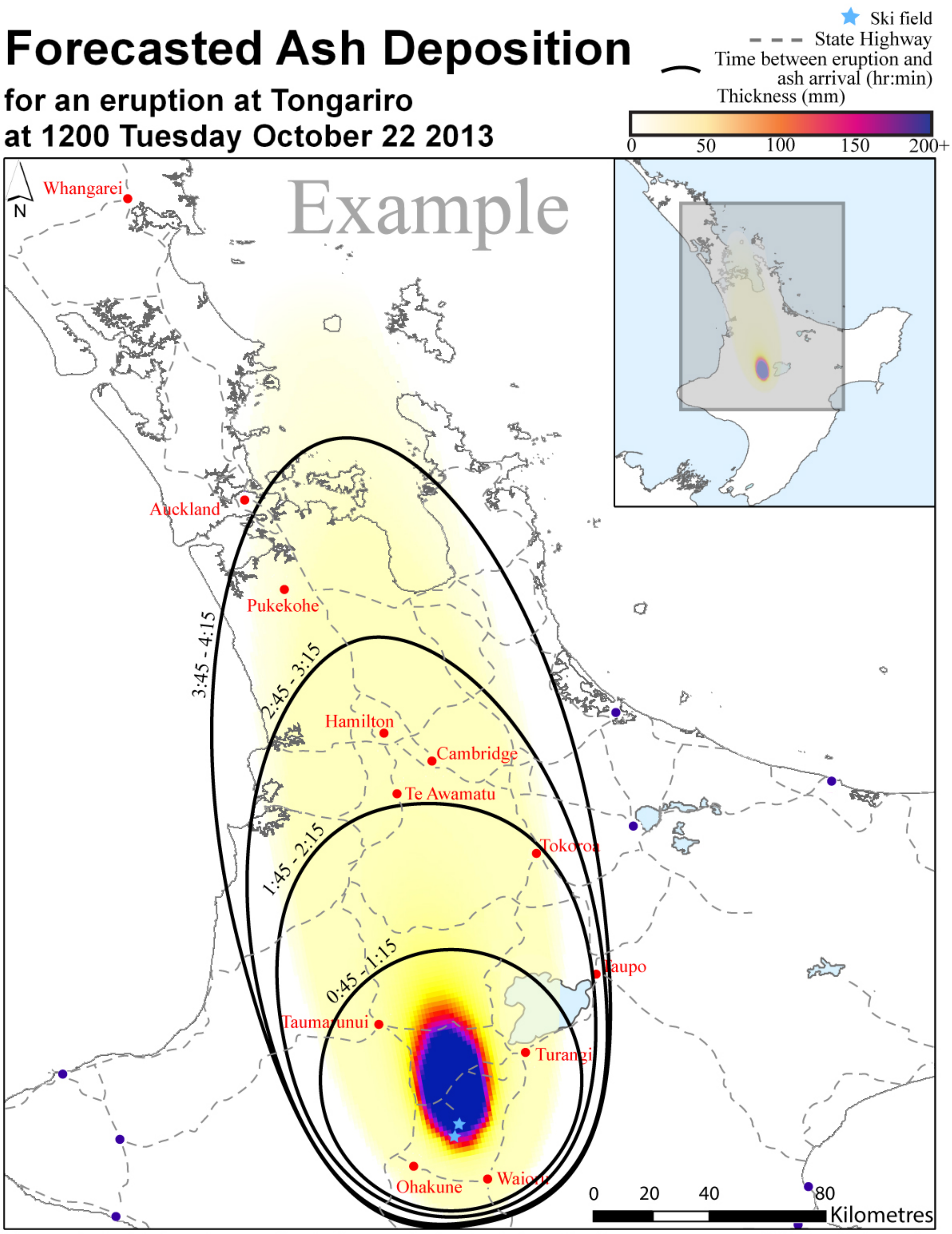
The final change to the information sheet, which was suggested by the majority of the stakeholders interviewed, was text explaining the model (what data it is based on, how it works, etc.). Four of the stakeholders interviewed feel that to fully determine how much confidence they can place in the forecast they have to understand how the model works, and where its possible shortfalls are. As things stand, they do not know how the map is produced or where the information comes from, they only know that somehow GNS produces a map which is passed along to them. They understand that it is a model and therefore has limitations and uncertainties, but they want to know exactly what those are. This sentiment agrees with the argument presented by McCarthey et al. (2007) that endusers need to know the uncertainty in the forecast so that they can factor it into their decision making process. To this end a paragraph was included in the information sheet which briefly explains how the model runs and where the data being used comes from:

> This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

A small body of text was also included beneath the table of towns and cities affected which gives some clarification.

4.2.4 Time

Time was not an attribute of the initial map because the literature found supporting it was limited. Also, some of the scientists at GNS stated that following the volcanic unrest at Ruapehu in 1996 and 1997, stakeholders were asked if they were interested in a time component being included in the short-term ashfall forecast map. The scientists stated that the general consensus at that time was that they were not interested and that expected ash depth was what was important to them. This is a good example of why practices should be re-evaluated regularly. While the stakeholders may not have been interested in how time relates to the forecast in the past, they are now. Six of the seven stakeholders interviewed requested for a time component to be added to the map, two of which mentioned it multiple times during the interview. One emergency manager for a large national company went so far as to state that if he had to choose between knowing when the ash would arrive and knowing how much ash he would receive, he would prefer to know when it will arrive. Over time people's needs may change with regards to what information is most helpful to them, and it is important to keep hazard maps up-to-date with regards to these needs. Time was added to the map in the form of contours showing how far the ashfall will reach within a certain time. It was also added to the additional information page in the form of textual ranges of expected time until arrival for all towns and cities affected. The times and ranges chosen for these maps were not accurate as the research needed to sufficiently forecast the time has not yet been conducted. The information was included on both pages in accordance with the idea presented earlier concerning what information should be on each page (Section 4.1.3).



For more in-depth information regarding the impacts of volcanic ash deposition (how to prepare yourself for it and what to do during it) please visit http://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/Eruption!-What-to-do

This is a model of how the ash will be deposited on the ground at the end of the event. For information concerning how the ash will interact with air currents and how this will affect air travel please visit http://www.caa.govt.nz/meteorology/Volcanic_Ash_Advisory_System.htm

Disclaimer: This forecast has been created using estimated values. It is possible that the ash will be deposited in a different manner than is depicted here. This forecast is supplied only as an aid for decision making and as such the issuing organisation bears no responsibility for any decisions made based upon this forecast.

Figure 4.2.1a: Second version of a short-term ashfall forecast map for a hypothetical eruption at Tongariro. This map shows how a large eruption would appear. This map was designed based off on information gathered from a review of the pertinent literature, interviews with scientists at GNS, and interviews with stakeholders from a variety of agencies.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Auckland	5-15	4:00 – 4:30
Cambridge	15-45	2:00 – 2:30
Hamilton	15-45	2:15 – 2:45
Ohakune	15-45	0:15 – 0:45
Pukekohe	5-25	3:15 – 3:45
Taumarunui	35-75	0:15 – 0:45
Taupo	0-2	0:45 – 1:15
Te Awamatu	20-50	2:00 – 2:30
Tokoroa	5-30	1:30 – 2:00
Turangi	25-65	0:15 – 0:45
Waioru	20-50	0:15 – 0:45
Whangarei	0-2	6:15 – 6:45

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Critical threshold levels:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs may begin to sag or collapse under the weight of the ash. It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

Figure 4.2.1b: A page of additional information which accompanied the map shown in Figure 4.2.1a.

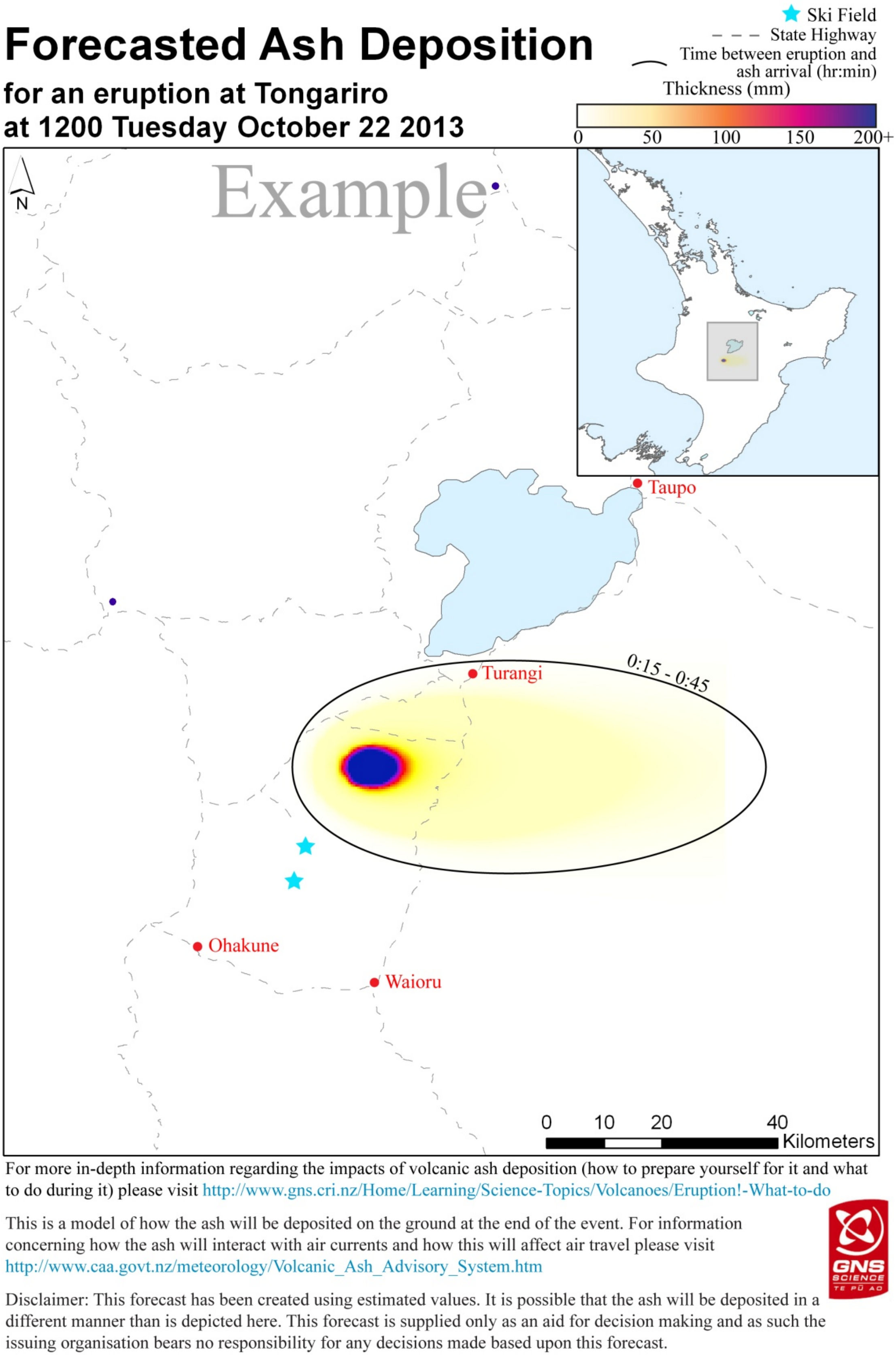


Figure 4.2.2a: Second version of a short-term ashfall forecast map for a hypothetical eruption at Tongariro. This map shows how a small eruption would appear. This map was designed based on information gathered from a review of the pertinent literature, interviews with scientists at GNS, and interviews with stakeholders from a variety of agencies.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Ohakune	0 – 1	0:30 – 1:00
Taupo	0 – 1	0:45 – 1:15
Turangi	0 – 10	0:15 – 0:45
Waioru	0 – 1	0:30 – 1:00

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Critical threshold levels:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

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>200 millimetres – Some roofs may begin to sag or collapse under the weight of the ash. It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

Figure 4.2.2b: A page of additional information which accompanied the map shown in Figure 4.2.2a.

4.3 Online survey

The next step in the development process for the map was to determine whether the information gathered from the interviews was an accurate representation of the target community at large. This was accomplished by creating an online survey which was sent to scientists and stakeholders, and which was completed by 38 people, which can be considered a good rate of response given the relatively small size of the field in New Zealand. Respondents came from all the sectors that the survey was targeting, such as scientific, governmental, and private business. Answers from the survey can be found in Appendix F (the questions asking for additional comments have been excluded so as to protect the anonymity of the respondents, as some of them include identifying information). The survey was used to affirm or contradict what had already been established, as well as gather new information and ideas which were not captured by the interviews. For a detailed look at the survey please see Chapter 3. As before, the results of the analysis of the survey responses were compared against the information which had been gathered in previous stages. The same process was followed as before with regards to disagreements between new information and established map elements. Almost all aspects of the map received a high level of support in the survey and therefore remained unchanged.

Not all elements received unanimous support, but those opposed to the established attributes were far outnumbered by those in favour of them, therefore they were not changed. The findings of the survey support both the idea that one size does not fit all (Broad et al. 2007) and the idea that with audience participation a single map can be created which helps a majority of users (Haynes, Barclay, and Pidgeon 2007). Throughout the survey there were multiple questions which received non-unanimous responses, with participants listing multiple different methods which would be best for them, or different pieces of datum which they would like to see added for the map to be more effective for them. These endusers have different needs, and as such their ideal map is not the same as another's. However, even though one universal map cannot perfectly match everyone's needs, one map can be created which is effective enough to be of aid to everyone. Though they may want different additional information, all endusers need the same general information regarding where the ash will fall, how long it will take to get there, and how deep the ash will become. The need for the issuing agency to decide how to address these competing ideas will be discussed further in Chapter 5.

Due to the purpose of the survey being to verify information gathered in both rounds of interviews, all of the individual attributes previously discussed in this chapter will be revisited. The response data for all of the elements included in the survey can be found in Tables 4.1 and 4.2. Note that standard deviation has no firm meaning with ordinal data, but it is included here for the purpose of giving an indication of the spread of answers. A large standard deviation means that there was more disagreement among the participants, while a small one indicates more agreement.

	Mean	Standard Deviation	Variance
Use of colour	2.81	0.52	0.28
Ski fields	2.25	0.55	0.31
Names of towns and cities	2.83	0.45	0.2
Locations of towns and cities	2.92	0.28	0.08
Inset map	2.44	0.61	0.37
Scale bar	2.69	0.52	0.28
Ash thickness scale bar	2.89	0.32	0.1
Disclaimer	2.39	0.55	0.3
Information regarding hazards of volcanic ash	2.58	0.65	0.42
Information concerning ash in the air	2.66	0.59	0.35
Forecasted ash depths table	2.86	0.35	0.12
Wind data	2.49	0.66	0.43
Critical thresholds section	2.42	0.75	0.56
Date and time of eruption	2.78	0.42	0.18
State highways	2.67	0.53	0.29

Table 4.1: Survey response data for the map depicting a large eruption. Participants were asked to score each element, with 1 = I very much don't like it, 2 = I am indifferent about it, and 3 = I like it very much.

	Mean	Standard Deviation	Variance
Use of colour	2.81	0.52	0.28
Ski fields	2.36	0.54	0.29
Names of towns and cities	2.89	0.32	0.1
Locations of towns and cities	2.81	0.47	0.22
Inset map	2.67	0.59	0.34
Scale bar	2.69	0.58	0.34
Ash thickness scale bar	2.89	0.32	0.1
Disclaimer	2.33	0.53	0.29
Information regarding hazards of volcanic ash	2.63	0.65	0.42
Information concerning ash in the air	2.61	0.64	0.42
Forecasted ash depths table	2.78	0.42	0.18
Wind data	2.57	0.65	0.43
Critical thresholds section	2.48	0.76	0.57
Date and time of eruption	2.92	0.28	0.08
State highways	2.57	0.61	0.37

Table 4.2: Survey response data for the map depicting a small eruption. Participants were asked to score each element, with 1 = I very much don't like it, 2 = I am indifferent about it, and 3 = I like it very much.

4.3.1 Colour

Similar to the stakeholder interviews, the use of colour in the maps received a high level of support in the survey. It received a mean score of 2.81 out of 3 in the survey, and only 4 elements out of the 15 listed scored higher than it. One respondent noted that only part of the colour spectrum used was visible when printed on a black and white printer. However, in this scenario (volcanic eruption in New Zealand) it is expected that few, if any, endusers will only have access to a black and white printed copy of the map (even those with black and white printers are assumed to have colour monitors). For the few that might be in this situation, the forecasted depths for all of the towns and cities expected to receive ashfall is included on the next page. Due to the high level of support the colour selection and usage was left as it was. If a large portion of the intended audience of the hazard map being created is expected to not have access to coloured representations of the map then research should go into determining which colours will be visible in all the common modes of display.

4.3.2 Scale

The decision to have the map set to a larger scale was supported by responses to the survey. When asked to critique a GNS-produced map of a small eruption one person wrote that "the map should be at a closer scale, value of info is lost because scale is too great to draw any sensible conclusions from", and another said that the "map is too zoomed out of eruption area." The survey responses also showed that the endusers are aware of the uncertainty in the map (which will be discussed further in Section 4.3.7) and do not associate greater certainty with a larger-scale map, as was feared by some of the scientists at GNS (Section 4.2.1). Since this concern has been shown to have no merit, there is no compelling reason to not have the scale change in accordance with the size of the event. However, it must be kept in mind that these findings may not hold true for every intended audience. The information provider must determine what the general level of knowledge is in their intended audience.

4.3.3 Additional information

The additional information page received a mixed response on the survey, however as a whole respondents were in favour of it. The approximate breakdown of the responses were:

Element	I dislike it very much	I am indifferent about it	I like it very much
Information regarding hazards of volcanic ash	8%	22%	70%
Information concerning ash in the air	6%	20%	74%
Forecasted ash depths table	0%	19%	81%
Wind Data	10%	27%	63%
Critical thresholds section	17%	23%	60%

Table 4.3: Table showing the approximate amount of responses each option received for all of the components of the additional information page.

Approximately 12% of the respondents wrote in the optional comments section to suggest some way that the additional information page could be improved. Some examples of suggested improvements include:

- "Should advise that where water supply is collected from roofs that down pipes are disconnected"
- "The small amount of information given of impacts of ashfall at different depths would be better replaced with instruction on where to find more information rather than just providing snippets"

However, there was no common theme or recommendation present in the suggestions. Therefore, due to the lack of a majority voice in calling for a specific change and the overall support for the additional information page, it was left as it was. The only update that was made to the page was changing the title of one section from "critical threshold levels" to "estimated impacts" for greater clarity. This change may have contributed to the lower level of support for this section as the name was changed on the information page, but not in the question in the survey, which led to some confusion. Approximately 15% of the participants wrote in the optional comments section that they were confused about what was meant by "critical thresholds section."

4.3.4 Base map

There were no calls for the base map to be changed in any way, therefore the base map used was seen as effective and remained unchanged.

4.3.5 Geographical information

As was mentioned previously, the responses to the survey showed both that one map cannot completely suit everyone's needs, and that one general map can be of use to everyone if executed well. This idea was present in the survey responses regarding what geographical information should be included. There was a generally high level of support for the inclusion of towns/cities (mean score of approximately 2.9 out of 3) and state highways (mean score of approximately 2.6 out of 3). However, in the optional comments section a couple of participants wrote suggestions for what geographical information they would prefer to see included. One person wrote “for me [it] would be useful to have rivers highlighted with their catchments clearly too”, and another wrote “I assume a map distributed to the utility companies would display additional power / water utilities.” Both of these comments are regarding how the map can be specialized for that particular participant. The amount of geographical information that is currently present is sufficient, but if given the possibility they would change it slightly to fit their unique needs.

The manner in which towns and cities were marked (differentiating between those likely to be affected and those likely to not be affected) was generally praised, and therefore left unchanged. One change that was made to them was to have all the town and city names in the same location in reference to the coloured circle, making it more uniform. The only attribute to not receive strong support was the markings for ski fields. The mean score in the survey for this attribute was far below the next lowest, with only approximately a quarter of the respondents saying that they liked having the ski fields marked. Some possible reasons for this result may be that none of the survey respondents came from the tourism field, or possibly because the ski fields are a seasonal attraction. One respondent stated that they did not see any point in marking the ski fields because if the erupting volcano were located in the centre of the North Island, the skiers would be the first to know of it due to their proximity. Regretfully, none of the survey participants represented the tourism sector, so their stance on the matter remains unknown. Due to the low level of support in the survey, and the lack of strong support in any other stage of information gathering, the ski fields were removed from the map.

The results of the survey also supported some decisions made earlier in the creation process. For example, when asked to critique a current-generation GNS map, approximately 84% of the respondents marked that the longitude and latitude markings were unnecessary (the decision to not include them on the map created for this research was made in the initial stages of development). The other areas that received the highest marks for being unnecessary were the wind data and the eruption volume, both of which were not included in the map created for this research.

4.3.6 Inset map

As was to be expected, the inset map received a lower score when critiqued as an aspect of a small-scale map (mean score of approximately 2.4 out of 3), but improved when critiqued as an aspect of a large-scale map (mean score of approximately 2.7 out of 3). As stated before, if the decision to include the inset map based on the scale of the main map can be reliably automated then it would be worth doing; otherwise, it is better to have the inset map on all maps than not have it on any. Due to this, the inset map is included in the final version of the hazard map. This is an area where each situation is unique enough and each intended audience will have different enough opinions that the decision whether or not to include a hazard map will be unique to each scenario.

4.3.7 Uncertainty

The results of the survey supported what was found in the stakeholder interviews, which is that the intended audience is well aware of the uncertainty involved in short-term hazard forecast and takes it into consideration when making their decisions. In the survey, approximately 90% of the respondents answered that they expect the map to be a good guide for how the ash will be deposited, but they expect that there will be some degree of variability between the forecasted and actual deposition. Also, there was no evidence of a decrease in trust associated with the greater inclusion of uncertainty (the GNS-produced map and the map created for this research receive almost identical scoring with regards to how much trust the enduser places in the accuracy of the map, as can be seen in Appendix F). Due to this and the support for including uncertainty found in the literature, the inclusion of uncertainty in the map (such as fuzzy boundaries, ranges of values, etc.) remained unchanged.

4.3.8 Time

The time component was graded in conjunction with the ash depths in the survey as they are in the same table. This table of information was one of the highest scoring map elements, with approximately 81% of the participants marking that they liked it very much, and none marking that they did not like it (the rest marked that they were indifferent about it). Also, in the optional comments section one person wrote that the "expected times of arrival are useful", and another stated "I prefer this map [as opposed to the GNS-produced map] as it is easier to read and has time scales." This supports what was found during the stakeholder interviews and reaffirms the need to periodically review established practices to ensure that they are still relevant, as in the past the stakeholders did not express interest in having a time component included. Seeing as the audience prefers the inclusion of time in the forecast and supports the methods that were used, the time components were not changed.

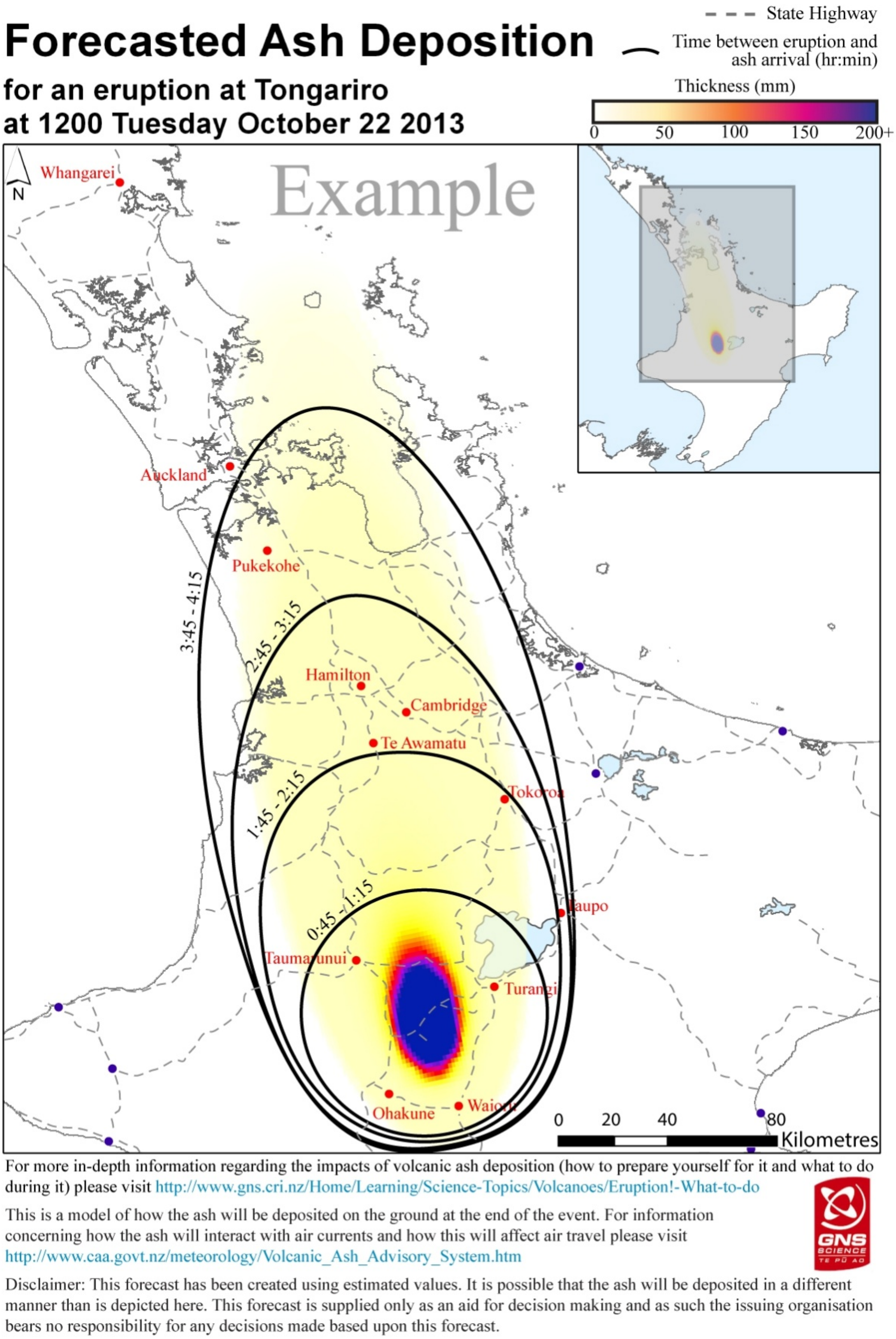

Figure 4.3.1a: Third version of a short-term ashfall forecast map for a hypothetical eruption at Tongariro. This map shows how a large eruption would appear. This map was designed based off on information gathered from a review of the pertinent literature, interviews with scientists at GNS, interviews with stakeholders from a variety of agencies, and a web-based survey.

For an eruption at Tongariro

At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Auckland	5-15	4:00 – 4:30
Cambridge	15-45	2:00 – 2:30
Hamilton	15-45	2:15 – 2:45
Ohakune	15-45	0:15 – 0:45
Pukekohe	5-25	3:15 – 3:45
Taumarunui	35-75	0:15 – 0:45
Taupo	0-2	1:15 – 1:45
Te Awamatu	20-50	2:00 – 2:30
Tokoroa	5-30	1:30 – 2:00
Turangi	25-65	0:15 – 0:45
Waioru	20-50	0:15 – 0:45
Whangarei	0-2	6:15 – 6:45

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs of residential homes may begin to sag or collapse under the weight of the ash (long-span roofs may begin to suffer damage before this point). It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

Figure 4.3.1b: A page of additional information which accompanied the map shown in Figure 4.3.1a.

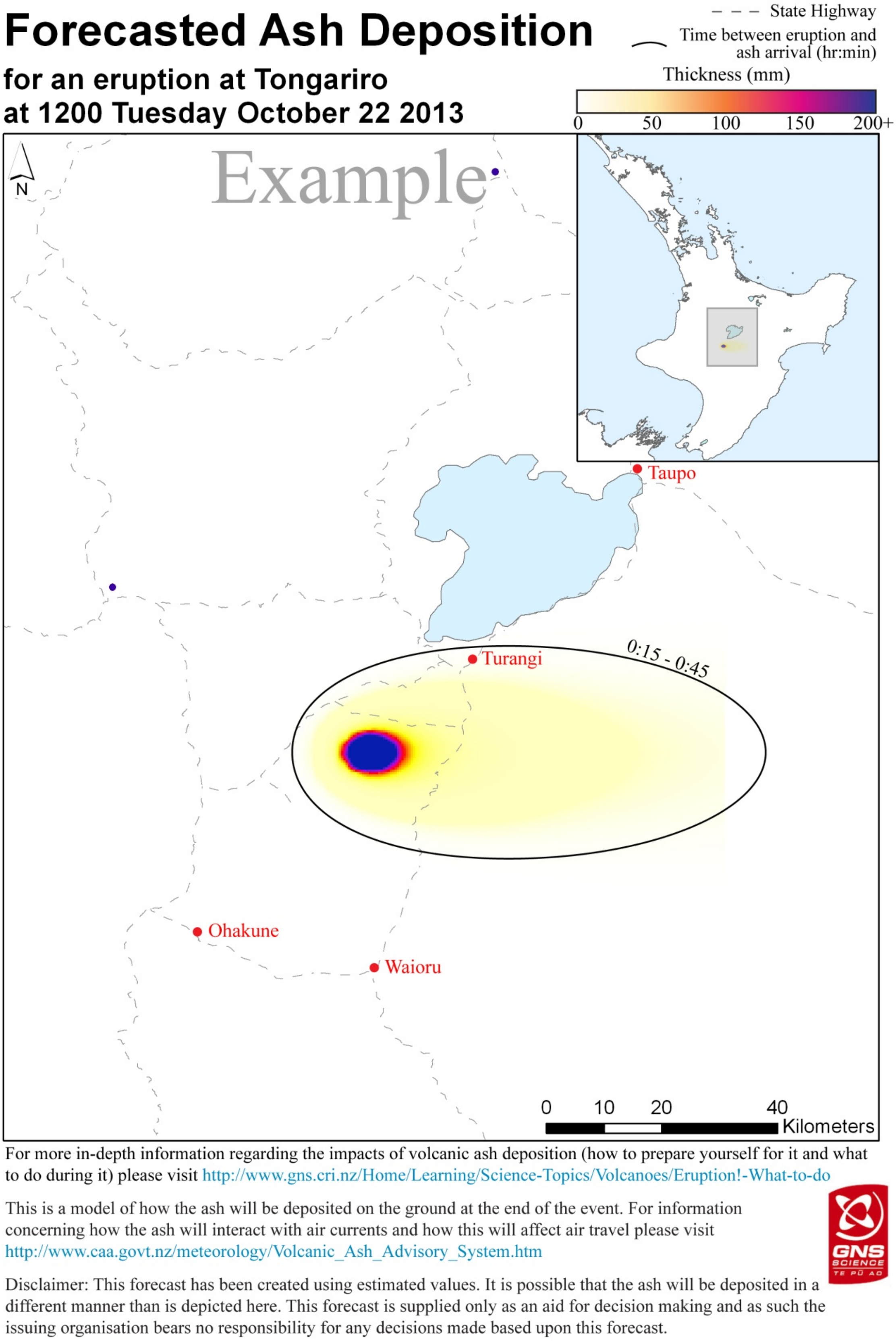

Figure 4.3.2a: Third version of a short-term ashfall forecast map for a hypothetical eruption at Tongariro. This map shows how a small eruption would appear. This map was designed based on information gathered from a review of the pertinent literature, interviews with scientists at GNS, interviews with stakeholders from a variety of agencies, and a web-based survey.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Example

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Ohakune	0 – 1	0:30 – 1:00
Taupo	0 – 1	0:45 – 1:15
Turangi	0 – 10	0:15 – 0:45
Waioru	0 – 1	0:30 – 1:00

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs of residential homes may begin to sag or collapse under the weight of the ash (long-span roofs may begin to suffer damage before this point). It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

Figure 4.3.2b: A page of additional information which accompanied the map shown in Figure 4.3.2a.

4.4 Summary

This chapter has shown that the creation of a hazard map must be a process. Different groups will have different preferences, and all must be considered when designing a hazard map. Each audience will be unique, and therefore each map will have different requirements it needs to fulfil. This chapter shows the process that this map went through to become the most effective short-term volcanic ashfall forecast map for stakeholders in New Zealand. To reach this point multiple changes were made based on the available literature, interviews with scientists at GNS, interviews with stakeholders, and a web-base survey. Table 4.1 shows a brief description of the findings for each attribute, divided up according to information source, and the final decision that was made for this map.

Attribute	Information gathered from literature	How scientists feel	How stakeholders feel	Final decision
Simplicity of the map	The map must be kept simple so as to be easy to understand quickly	Agree with the literature, must be kept simple	Agree with the literature and scientists	The idea of keeping the map simple and concise was kept in mind while making design decisions
Base map	The base map style must be practical and one with which the intended audience is comfortable and proficient	Due to the variety of backgrounds in the audience and scale of the maps, a plan view of the coastlines is best	Like the simple plan view outline; they were all comfortable with it	Plan view of the coastlines; too small-scale for aerial photography to be practical
Map scale	The scale must match the size of the event so as to adequately display the information	Reluctant to use large-scale maps as they fear that endusers will interpret greater scale to mean greater certainty	Very strongly prefer to have large-scale map for small eruption; understand separation between scale and certainty	Map scale is determined by the size of the event, due to endusers understanding the uncertainty involved
The use of colour	Can be of great benefit and help display more information, but must be used appropriately	Split opinions; some support the use of colour while others fear that it will put those without colour printers at a disadvantage	Very strongly prefer to have colour included and used to convey more information	Colour included; it was determined that not enough endusers should have trouble accessing the map in colour for it be a concern
Geographical information	There should be enough for people to locate themselves and the hazard; commonly used items are roads, rivers, towns, etc.	Split opinions; some feet that only towns are enough while others want additional information such as highways	All agree on the basic items (cities/towns and state highways), but some want more such as rivers, land use markings, infrastructure, etc.	Cities/towns and state highways; while other information would be useful for different groups, it would get cluttered quickly and only satisfy some
The inclusion of uncertainty	Split opinions, but more support for including it than not; many different ways to include it presented	Split opinions; some feel that it would be good to include, but others feel that not enough is known about the uncertainty in the model to comment on it	Understand the limitations of a model and support the inclusion of uncertainty in the map	Uncertainty was included both visually (fuzzy contours) and textually (values presented in ranges, text explaining that the model is based on estimations)
Time	Only a small amount of literature was found discussing it, and it was in favour of including it	Split opinions; some feel that it would be good to include while others feel endusers are not interested based on past surveys	Very interested in having time included on the map	Included in both the map and additional information page

Table 4.4: Information gathered on each map attribute, separated by source, and the final decision made for each attribute with regards to the map created.

Chapter 5 Discussion and conclusions

In this chapter the findings of the research will be presented. First the similarities and differences between the information providers and endusers will be discussed. Next, each of the key attributes which have been focussed on throughout this paper (summarised in Table 4.4) will be evaluated. After the map itself has been reviewed, this chapter will discuss how these maps fit into the larger picture of natural hazard mitigation. The chapter will then conclude with an evaluation of the strengths and weaknesses of the methodology that was used.

5.1 Information providers versus endusers

For a hazard map to be effective it must satisfy both the information providers (in this case GNS) and the endusers (the stakeholders). There will be areas in which these two groups agree, and other areas where they may disagree. In this research there were differences of opinions between GNS and the stakeholders with regards to the design of the map, such as what scale the map should be at, or whether or not colour should be included. All of these differences were minor and a solution was found which satisfies the majority of the participants.

However, there is a significant opposition of preferences with regards to how the data is handled and analysed. In addition to the map, almost all of the stakeholders want the information provided to them in the form of a file, which they can upload into their own system to analyse. The stakeholders feel that they can do a better job of analysing the impact of the ash on their assets than GNS can, because it is their field of expertise. However, they need the information concerning the ash in their system to complete the analysis. Some of the scientists at GNS are very reluctant to release such a file because they feel that it would put too much power into the hands of the endusers. The scientists are afraid that the stakeholders do not understand the limitations of the information well enough to allow them to load it directly into their own systems where they can manipulate it and extract extremely detailed information. No steps were taken to solve this contradiction, as it is something that the scientists and the stakeholders must determine between themselves. As Fisher (1991) explains, the relationship between the information provider and the enduser should be one of two-way communication, with the information provider taking into account the concerns and preferences of the enduser. However, the interviews and survey did show that the stakeholders have a higher understanding of the model and its uncertainties than the scientists currently attribute them.

5.2 Map elements

5.2.1 Simplicity of the map

The literature, scientists, and stakeholders all agree that the map needs to be kept simple so that it is easy to understand quickly. However, this does not mean that the provider can only communicate a minimal amount of information. There are other ways for the information to be conveyed than on the map, such as with an additional information sheet, as was done for this project. Also, the type and amount of information that would be considered “simple” will vary depending on the intended audience and what is being mapped.

5.2.2 Base Map

The style of base map used depends on the intended audience and the information being communicated. The style chosen must be one that is effective at communicating the information, but also one with which the intended audience is familiar. For this research the optimal option was a simple plan view of the coastlines and major bodies of water. This map style received a large amount of support from both scientists and stakeholders, and therefore its use for an ashfall map should be considered non-controversial. However, other types of base maps may be more effective for different audiences and hazards. The literature states that aerial photography can be effective for endusers who are not familiar with reading maps

(Haynes, Barclay, and Pidgeon 2007). However, aerial photography would only work if the hazard being mapped is a local one, or if the map is only focusing on the local effects of a large hazard, as it is not feasible to use aerial photography to depict a large area. Contours maps are also listed as being especially effective at conveying information (Nave et al. 2010). While contour maps are able to depict a larger area than aerial photography, they can also be confusing to people who are not practiced in using them. The creator of the map must also consider what hazard is being mapped, and how the information will be displayed, as some hazards might communicate better on a certain map base than others. For example, for an earthquake hazard map, if the map is using contours to show peak ground acceleration, a contour map may not be the most appropriate base as the overlapping contour lines might be confusing.

5.2.3 Map scale

The scale of the map must match the scale of the event, or the portion of the event that is of interest, so as to adequately display the information. If the scale of the map is too large, not all of the information will be shown, and if the scale is too small the information may be hard to see. How the endusers will interpret the data must also be considered. In this research, some of the scientists were concerned that using a larger scale (e.g. 1:1000 rather than 1:10,000) for the map would convey more certainty in the information, leading to a misuse of it. The interviews and survey found that the stakeholders understand the uncertainty associated with the model, and therefore it would not be detrimental to increase the scale of the map. However, this may not be the case for other intended audiences.

5.2.4 The use of colour

Whether or not colour should be used on the map depends greatly on the audience. If all members of the intended audience are expected to have access to a colour version of the map, as was the case in this research, then it should be included as it can help convey more information. However, if a significant portion of the intended audience will not have access to a colour version (e.g. the map will be printed and distributed, and a colour printer is not available), then the map should be designed as a black and white image. It is possible for specific colours to be used which keep their relative values when displayed in black and white. If there is enough of a desire to include colour in the map then research should be put towards determining which colours keep their relative values when displayed in the available black and white mediums. The colour scale used to represent ashfall on the maps in this research was successful in keeping their relative values when printed on a black and white printer. However, the colours were not tested on multiple different printers and photocopiers.

Determining whether or not to use colour is only part of the process. The other part is to determine how the colour is used. While the inclusion of colour can greatly help a map, it can also make it more confusing. If colour is used, it must be used in a way that enhances the information for the intended audience. Also, certain colours have distinct connotations in some cultures, and this must be kept in mind when choosing what colours to use. For example, in many Western cultures red represents danger and green represents safety, whereas in other cultures red has a positive connotation, even being seen as lucky by some. Some colour schemes may need to be avoided due to the connotation of certain colours included in them. For example, a red to green scale was not used on the maps in this project because any area that is coloured on the map will be receiving some amount of ash, and therefore should not be marked with green as users may equate the colour with clear conditions. However, the connotations of some colours may prove useful. For example, an inundation forecast map might choose to use a dark to light blue scale for marking water depth, as some people will automatically recognise the dark blue to represent deeper water.

Those who are colour blind must also be considered when creating a map. Incidences of colour blindness are high enough that it should be considered a high probability that someone who is colour blind will view the map at some point. As such, consideration should be given to avoiding colour schemes which make use of problematic colour pairings such as red/green and blue/yellow.

5.2.5 Geographical information

The map must contain enough geographical information for the user to determine their location and/or the location of their assets in relation to the hazard. What type of geographical information is used depends on the scale of the map, the hazard being mapped, and the intended audience. If the map shows how the hazard affects a single community, then it would be best to use information and landmarks that the local community is familiar with such as town features or local roads. However, if the map covers a large region then it would be best to avoid local geographical information and use more general ones that everyone would be familiar with such as state highways or well-known rivers. Also, some hazards will require different geographical information to be displayed than others. For example, roads might be found on an inundation map due to the need to evacuate, but not on a shake map since evacuation is not a primary concern. Finally, the geographical information must be applicable for the intended audience. Different endusers are familiar with different types of geographical information due to their experiences, and the map must include information that they are comfortable with. Also, some endusers may want a specific type of information present on the map because how the hazard will impact that information is important to them. For example, a power company that uses rivers for hydroelectric power may want to have rivers on the map so that they can see which ones will be affected.

One of the challenges associated with creating a hazard map is determining what geographical information does and does not get added to the map. As has just been shown, there are many factors to consider. It is especially difficult if the intended audience for the map includes people from multiple sectors who have different needs. The map must be designed so that there is enough information included for it to be an effective map for everyone, without including so much that it becomes too cluttered (as was discussed in Section 2.3). Too much clutter can lead to cognitive overload, which decreases the efficacy of the map (Doyle and Johnston 2011). One possible solution to this challenge would be to send a file of the ashfall information to all of the endusers for use within their own systems. If the endusers have a file that they can work with they are able to add the geographical information that is more pertinent to them without the worry of affecting someone else. This idea received nearly unanimous support among the stakeholders interviewed for this research. However, it should be remembered that some of the scientists are opposed to this due to their fear of the information being misinterpreted or misused (see Section 5.2).

5.2.6 The inclusion of uncertainty

Deciding whether or not to include uncertainty and deciding how to display it if it is included are both difficult tasks. Past research on the subject is divided. Some argue that including uncertainty empowers the enduser (Kootval 2008) while others fear that it reduces trust in the organisation issuing the map if the enduser doesn't fully understand it (Doyle et al. 2011). This research found that same division of opinion, with the stakeholders feeling that they can make better decisions if they are aware of the level of uncertainty in the map, and scientists afraid that they will misinterpret it and thus misuse the information. Therefore, the decision concerning whether or not to include uncertainty depends on the level of understanding of the intended audience.

When creating a hazard map, a person must also consider how well defined the uncertainty is and how it can be presented. There are multiple ways of including uncertainty, both visually and textually (see Section 2.4). Different maps may benefit from different methods of display. If the uncertainty associated with the map is unknown, or if it is not critical to know the exact amount, then a more broad approach such as blurring the boundaries between contours (as was done in this project) may be more appropriate. However, if it is important to know the exact amount of uncertainty (for insurance purposes or impact assessments), then a text-based approach might be appropriate since it can be more clearly shown.

5.2.7 Time

Whether or not a time-based element is included in the map depends on the preferences of the intended audience, the style of the map (a 500 year return period map versus a short-term forecast), and what hazard is being mapped. If the intended audience feels that having a time component to the map would not be beneficial for them, there is no reason to include it. It is not a necessary component of a hazard map like the base map and geographical information are. A time-based element also need not be considered if the style of the map is one which takes a long-term approach. If the map is showing data such as a compilation of historical averages of past events, or the results of a probabilistic study, there is no need for the element, as the map is not forecasting short-term impacts. Finally, for a time component to be practical the hazard must be one which can be forecasted reliably. Current technology is unable to estimate when an earthquake will hit, therefore a time-based element is not commonly included.

5.3 Putting it into context

Now that the research has been completed and the ashfall forecast map designed, it is important to evaluate what can be learned from this research. This section will focus on what lessons researchers in New Zealand and from other parts of the world can take away from this research. These lessons can also be applied to other types of hazard maps.

5.3.1 Revaluating practices

Established practices must be revaluated periodically. Needs and preferences change over time, therefore the associated practices must be reviewed to make sure they are still the most appropriate. An example of this, which has already been mentioned several times, is the inclusion of a time-based component in the map. The idea of a time element was not a new one. Scientists have considered this before, and GNS has been using the same modelling programme for approximately twenty years, so their capability to produce such an element has remained the same. The reason this element was never added is because the stakeholders did not express interest. Following the 1995-1996 Ruapehu eruptions the stakeholders were asked if they were interested in seeing a time-based component added to the map, and their response was no. This became the established standard, and scientists still think that this is the case, because they have not heard otherwise. However, when asked if they would like to see such an element added, the current stakeholders responded with a resounding yes. The scientists were not wrong to exclude such a component in the past, as the stakeholders were not interested. However, since the practice had not been revaluated it was incorrectly assumed that this was still the case.

Another example of the need to revaluate practices involves the inclusion of colour in the maps. When asked their opinions on including colour, several of the scientists at GNS were against it. Their reasons for being against it were that the alert bulletins (which include the map) are still sent out by fax, which can't convey colour, and that not everyone has access to a colour printer. In the past, these were valid reasons for not including colour in the map. Now, however, access to colour printers is much more ubiquitous, and GNS no longer sends the alert bulletin by fax. With these two changes, there is no longer a valid reason for the map to not include colour (as stated before, this will not be the same for all locations, this only applies to this situation). Both of these practices were valid and logical in the past, but times have changed and so must the practices. All established practices should be periodically reviewed to ensure that they are still appropriate. Practices can be periodically reviewed through (but are not limited to) workshops, seminars, exercises, and surveys.

5.3.2 Communication

There must be communication occurring between everyone involved with the hazard map. The information provider should be communicating with the endusers, and the endusers should be communicating amongst themselves as well. The information provider should be communicating with the endusers to determine how educated they are on pertinent information, what information they need, and what methods of display are most effective for them. The map must be designed to be as informative as possible while still being at a level that the endusers can understand. There should be input from both sides, working together as peers, to reach this goal.

As has been mentioned, some of the scientists at GNS underestimate how educated their audience is. It is not the case everywhere, but in New Zealand the stakeholders have enough training and experience to make them well educated and able to understand a higher level of information than is currently being given to them. As mentioned above, the scientists at GNS think that the stakeholders do not understand the uncertainty in the model, and therefore are reluctant to provide them with a file to work with, which is limiting the stakeholders' ability to respond. The scientists at GNS should communicate with the stakeholders in order to determine what level of information they are capable of utilising. The end goal should be a shared awareness of each other's needs and responsibilities.

Endusers should also communicate amongst themselves so that they can know what to expect of one another and what the others are comfortable with. An example of this is a contradiction that arose between the stakeholders from the Auckland Engineering Lifelines Group (AELG) and the stakeholders representing Civil Defence. The stakeholders from the AELG feel that information regarding actions during an event should not be on the map as that is the role of Civil Defence. However, the stakeholders from Civil Defence were very supportive of the information being included in the map. The stakeholders should communicate with each other so that those from the AELG understand that those from Civil Defence support GNS providing that information. Without the statements from the stakeholders representing Civil Defence, the information may have been removed, to the overall detriment of the map.

5.3.3 The individual versus the group

There are three ways in which the information provider can approach the task if communicating hazard information. Those three options are:

- Provide multiple maps, each one containing information specific to a certain sector.
- Provide the data directly to the endusers and allowing them to load it into their own systems.
- Provide a single map which attempts to contain enough information to satisfy everyone without including so much that the map becomes over-saturated.

As has been shown, the individuals within a group will have different specific wants and needs. If the information provider is more concerned about making sure each person/organisation in the group is fully satisfied, then one universal map is not adequate. The information provider must either create unique maps for each set of needs, or create a universal file that they give to everyone to upload into their own system to manipulate as they see fit. One option results in a much larger workload for the information provider, and the other forces them to relinquish control of the information and trust that the endusers will use it appropriately. However, one map can be designed well enough to satisfy multiple parties. If the information provider is more concerned with satisfying the group as whole they must create a universal map, which contains enough information to satisfy all of the endusers yet not so much that it becomes confusing. For this approach to be effective there must be communication and consultation between the information provider and the endusers to ensure that the map is designed appropriately to satisfy everyone. This was the option chosen for this research project, as response time is a critical component of mitigating the hazards of ashfall. Creating multiple unique maps would create too much work for the duty officer. Either some groups would get their map before others, which would cause discord among the organisations and malcontent towards GNS, or everyone would get their maps at the same time but it would be delayed, which is not an option for some of the organisations. However, it is recommended that more research and dialogue be focused on the option of providing the endusers with a file to load into their systems (discussed in greater depth in Section 5.1). This is a challenge that all information providers will face, regardless of the hazard that is being mapped. Therefore, all should follow this process (deciding which approach to take and discussing it with the intended audience) to determine what the focus should be for their map.

5.3.4 Education and outreach

Something that will help make hazard maps more effective is education and outreach (Gregg et al. 2004). Every intended audience will be different, but this research found that despite the high level of understanding among the endusers, there are still areas where they need more training. For example, less than half of the survey participants knew that the GNS-produced ashfall forecast is based on current wind conditions, as opposed to historical averages (discussed further below). However, the stakeholders had a higher level of understanding than many of the scientists expected or gave them credit for, and therefore more information was able to be included on the map. This leads to a more informed audience, and a more informed audience is better able to prepare for and respond to a natural hazard. However, there were still areas where the stakeholders did not know very much because it had not been explained properly to them. The confusion concerning the wind data that is inputted into the model that creates the map is a good example of this idea as well. Some stakeholders even asked if they would get a new, updated map each time the wind changed. Because of their lack of understanding with this, many of them were misinterpreting the map and would have misused it during an event. Without the knowledge that the model accounts for all of the forecasted changes in the wind pattern many of the stakeholders were putting less trust in the map and some would have even considered it no longer applicable once the winds changed.

This shows why it is important to ensure that the intended audience is educated. It is of no use to improve the map and add more components or information if the audience does not understand it. The endusers should be contacting the organisation issuing the map if they have questions about it, but ultimately it is the responsibility of the information provider to ensure that the product they are delivering is being understood.

All information providers, regardless of the hazard they are mapping, will face this challenge at some point. Not everyone in the intended audience will understand every aspect of the hazard map. Information providers should communicate with members of the intended audience to determine if there are any elements of the hazard map which are not understood. Sometimes the result of these discussions will be the endusers becoming more educated. Other times the result will be a change to the map, when it is determined that the approach taken is not the most appropriate for the intended audience. Both parties should be considered equal peers in this dialogue.

5.3.5 Audience feedback

This research has shown that giving the intended audience the opportunity to participate in the creation process of a hazard map is critical. Not only does it ensure that the map is designed in a way that they will understand (as discussed above), but it also leads to a greater “buy-in” with the map, so to speak. People are more willing to use an item and put more trust in an item if they had a hand in creating it. It is the same with hazard maps. If an enduser is simply given a map to use, they may not put as much trust in it because they feel like it doesn’t meet any of their needs, and that the issuing organisations doesn’t actually know what is important to the enduser. Conversely, if the enduser is included in the creation process they will feel that their needs have been acknowledged, and even if all of their requests were not met, at least they were considered. Including the enduser builds the level of trust between the information provider and the audience. This trust is necessary for the map to be effective. If the audience does not trust the organisation issuing the map, or if they feel that the map is not applicable to them, it does not matter how effective map is, since they won't be using it (Haynes, Barclay, and Pidgeon 2007). For the map to effective the intended audience must "buy into it". The way to achieve this goal of trust and acceptance is continued dialogue between all parties involved. If the information providers have an established pattern of communication with the endusers and repeatedly turn to them for input it will build the rapport and trust needed to establish a continuing collaboration. Continued communication will also help ensure that changes in stakeholder needs are noted and implemented quickly (see Section 5.3.1).

5.3.6 A step in the process

A hazard map is only one facet of an effective natural hazard mitigation strategy. Each location should find what activities are most effective that region, but two that work in conjunction with publishing a hazard map are holding exercises and making additional information available elsewhere. Mock events are important because it gives everyone involved some experience regarding the situation. Even though it is not as hectic or stressful as a real event, mock events help people familiar with what they need to do, and it highlights areas that need more focus. For this research project the interviews and survey found that only a small portion of the intended audience for the hazard map have any experience using the map to respond to a natural hazard. Many of the stakeholders interviewed said that they had seen one before, but for many of them it had been a long time since they saw one and only one interviewee had used one. For the endusers to be effective in their response they need to practice using the hazard map so that they are familiar with it. Exercises such as these are being conducted in New Zealand for volcanic hazards, but they are not reaching a wide enough audience, as most of the current stakeholders do not have experience using the ashfall forecast map.

It is also important to have additional information (such as a detailed report of what ash can do to power lines, or where all of the evacuation centres are located) provided elsewhere for the people that want to know more. Even with the additional information page, the hazard map can only contain a certain amount of information. Having information in other, easy to access places such as pamphlets and websites allows people to study more in-depth the topics that are of interest to them without over-saturating the map. In this project this was accomplished by placing several website addresses below the map which lead to websites that provide more information.

5.4 Lessons emerging from this research

This section will briefly summarise four lessons which have been learned during this research, and which are discussed in greater depth in other sections of this thesis.

Lesson 1: Some of the assumptions that the scientists hold about the stakeholders are invalid. One incorrect assumption is that the stakeholders do not understand the uncertainty in the map. This understanding influences how the scientists design the hazard map, as they will try to design it in a way that is most effective for the intended audience. If the views and assumptions are incorrect, then the map is not being designed in the most effective manner. An ongoing dialogue between the scientists and the stakeholders can help to solve this problem.

Lesson 2: Some of the assumptions made by the scientists regarding what information the stakeholders need on the map can be improved from this research. One area that this research has helped to clarify is how the stakeholders feel concerning including a time-based element in the map. The scientists have discussed with the stakeholders what information they would like to see on the map. However, in-depth conversations could be occurring more frequently. The last time the stakeholders were specifically asked about how they felt concerning a time-based element was in the 1990's. The information that the scientists gathered at the time was accurate, but that information is no longer current (Section 4.2.4). The needs of the stakeholders evolve over time, and therefore what they are wanting from the hazard map will change as well. If the information on the map does not reflect what the stakeholders need to fulfil their responsibilities, then the map is not as effective as it could be. A possible solution would be establishing or expanding a continuous dialogue between the scientists and stakeholders, which periodically reviews established practices.

Lesson 3: The stakeholders would prefer to receive an electronic file that contains the hazard information, which they can load into their own geospatial mapping systems (i.e. GIS). This would allow them to make use of all of their own data and better analyse how their assets will be affected. However, as discussed in Section 5.1, some of the scientists are concerned that the information may be misused if provided in this way. The scientists and stakeholders should discuss this option and reach an agreement that both are comfortable with. This hearkens back to the need for a dialogue between the two. A robust two-way communication would help the scientists understand what level of comprehension the stakeholders possess, and what they would prefer, as well as help the endusers understand the concerns of the scientists.

Lesson 4: The final lesson was that the mixed-method approach to the research was more fruitful than only employing one of the two methods (interviews or a survey). The combination of the two allowed for both qualitative and quantitative data to be gathered, which allowed a wide sample to be collected (survey) but was complimented by good depth and context from the interviews. Also, the scientists and stakeholders who produce and use the maps were the ones who determined the topics for which quantitative data was gathered, therefore limiting any biases or limitations in understanding that the author may have had.

5.5 Strengths and Limitations of the methodology

To be effective a hazard map must take into consideration previously established “best practices”, as well as present the information in a way that is effective for the intended audience. To make it effective for the audience, information must be sought from both the information providers and the endusers. The methodology that was chosen for this research attempted to incorporate all sources of information by starting with a literature review, conducting interviews with scientists and stakeholders, and finishing with a web-based survey (see Chapter 3).

A strength of this methodological approach is that it gathered information from all three areas: previously established “best practices” (literature), information providers (scientists), and intended audience (stakeholders). Another strength of this mixed method approach (interviews and a survey) is that time and effort were able to be focused on a small group of people in order to gain detailed information, which was then able to be verified as representative of the whole group via the survey. The survey provided quantitative data, which was used to evaluate how much support each map element had, and by consequence what elements, if any, should be changed. Conversely, the interviews provided the qualitative data. The open-ended questions in the interviews were necessary to establish the base from which the quantitative data could be gathered. This was exploratory research, and therefore it was dependant upon the participants to determine the points of interest from which a survey could be developed. The use of open-ended questions allowed the interviewee to express any thoughts they had that they felt were relevant. It did not constrain them to pre-determined answers. They also allowed the interviews to go into greater depth on some topics and gather richer data.

The iterative process that was used in the creation of the map was effective because it allowed for the stakeholder interviewees and survey participants to have something specific to critique. They were able to see what had been previously recommended and determine if they thought it was effective. In this way the research was able to incorporate their ideas, as well as refine previous suggestions. Also, seeing some elements that others had recommended might have caused the participant to think of something new that they had not previously considered. This approach was more effective than first attempting to gather all of the information and preferences, and then create one map that satisfies all of them.

One possible drawback to the mixed method approach is that the ideas of the survey participants are not put up for consideration by anyone else. The participants were given the option to write additional comments at multiple points throughout the survey to ensure that they had to opportunity to voice their ideas as well. These comments were checked to see if there was a theme or themes that occurred frequently enough to warrant consideration. However, it is possible that a survey participant could have had an idea that was uncommon enough to not have others suggest it as well, yet effective enough that it would have received a high level of support had others seen it. Another possible limitation of the chosen methodology was the use of open-ended questions in the interviews. Due to the interviewees freedom to discuss anything they felt relevant, it is possible that the answers were not as specific and direct (and therefore effective) as they could have been.

5.6 Areas for future work

While this research has helped answer some questions and improve the effectiveness of hazard maps, it has also identified some areas where more research needs to be done. One such area is the inclusion of a time-based element in the map. Not a large amount of literature was found concerning including or excluding a time element, nor how to best display such an element if it is included. This research found that the endusers were very interested in having a time-based element included. However, due to a lack of prior research it was uncertain how to best represent the time in a way which incorporated the uncertainty associated with it. For this research it was decided to display the full range of time (e.g. 3:45pm – 4:15pm). Future research should be conducted to determine what manner of display is most effective.

Another area which would benefit from more research is determining how detrimental it is for the endusers to use data without fully understanding the uncertainty in it. One of the largest concerns of the scientists who participated in this research is that the stakeholders do not understand the uncertainty behind the data. This fear was the reason the scientists did not want to set the map to a larger scale, provide the endusers with a file to work with, or even display the uncertainty on the map. Some of the scientists feel that the only way to make sure that the endusers used the information correctly is to provide them with a basic static map that is set to such a small scale that the stakeholders are not able to see any details and are therefore forced to make assumptions and estimations. They feel that doing this prevents the stakeholder from being too specific and forces them to recognize the uncertainty since they themselves have to make estimations. On the other hand, the stakeholders feel that they understand the uncertainty and therefore want extremely detailed information. Every organisation that publishes a hazard map should conduct their own research to determine how knowledgeable the intended audience is with regards to the uncertainty in the map. However, a wider scope of research should also be undertaken to determine the relationship between the endusers explicit understanding of uncertainty and the effect that such an understanding has on their decision-making.

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Appendix A
Ethics information for interviews with GNS scientists.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

LOW RISK APPLICATION FORM

(For research proposals which are not considered in full by the University Human Ethics Committee)

FOR STUDENT RESEARCH UP TO AND INCLUDING MASTERS LEVEL

ETHICAL APPROVAL OF LOW RISK RESEARCH INVOLVING HUMAN PARTICIPANTS REVIEWED BY DEPARTMENTS

Please read the important notes appended to this form before completing the sections below

1 RESEARCHER'S NAME: Nathanael Baird

2 NAME OF DEPARTMENT OR SCHOOL: Geology

3 EMAIL ADDRESS: nate.baird@pg.canterbury.ac.nz

4 TITLE OF PROJECT: What's in a map? Communicating natural hazard information to stakeholders

5 PROJECTED START DATE OF PROJECT: 1 March 2013

6 STAFF MEMBER/SUPERVISOR RESPONSIBLE FOR PROJECT: Tim Davies

7 NAMES OF OTHER PARTICIPATING STAFF AND STUDENTS: Erik Brogt, Tom Wilson

8 STATUS OF RESEARCH: (e.g. class project, thesis) MSc thesis

9 BRIEF DESCRIPTION OF THE PROJECT:

Due to the geologically active nature of New Zealand the country is susceptible to various natural hazards, one of which is volcanic eruptions. The ash that falls across the ground as the result of an eruption can travel long distances due it's low density, and poses a threat to human and animal life, as well as to critical infrastructure. Due to this, stakeholders (local councils, infrastructure and agriculture managers, etc.) need information regarding an eruption as soon as possible so that they can make decisions regarding how to best protect their interests. GeoNet currently produces an ash fall forecast map which shows where the ash is expected to fall, but this map was designed almost twenty years ago and has not had any majors changes to it since. The aim of my project is to determine what information these stakeholders need immediately following a volcanic eruption in order to make informed decisions, and determine how to provide/display this information most effectively. I will use this information to design an improved ash fall forecast map using the inputs that are currently available. In the first phase of the study, to which this application pertains, I will gather my information by way of a literature review as well as speaking with people who are knowledgeable on the subject matter, such as the creator of the modelling program which provides the information used on the maps, a current volcanic hazard specialist at GNS, etc. I will then use the information gathered to create several different map designs.

In a subsequent phase of the study, I will use qualtrics to create a survey to accompany the maps designs, and I will email the survey and maps to stakeholders throughout New Zealand who are close enough to a volcano for it to be a pertinent hazard. The survey will ask the stakeholders to critique the different maps, and I will use these critiques to make any necessary changes and arrive at the best fit map(s). A separate ethics application will be filed for the second phase of the study in due course.

10 WHY IS THIS A LOW RISK APPLICATION?

The first phase of the study is low risk because the people interviewed are professionals working in the field who will be asked for their professional views / opinions. They may be identified by name in the thesis.

11 PROVIDE COPIES OF INFORMATION & CONSENT FORMS FOR PARTICIPANTS

These forms should be on University of Canterbury Departmental letterhead. The name of the project, name(s) of researcher(s), contact details of researchers and the supervisor, names of who has access to the data, the length of time the data is to be stored, that participants have the right to withdraw participation and data provided without penalty, and what the data will be used for should all be clearly stated. A statement that the project has been reviewed approved by the appropriate department and the University of Canterbury Human Ethics Committee Low Risk Approval process should also be included.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Nate Baird
Department of Geological Sciences
Tel: +64 021 0220 0584
Email: nate.baird@pg.canterbury.ac.nz

Dear [enter name here],

My name is Nate Baird and I am a Masters thesis student at the University of Canterbury in the hazard and disaster management program, supervised by Tim Davies, Erik Brogt, Tom Wilson (all from the University of Canterbury) and Emma Hudson-Doyle (JCDR, Massey University). I am writing to ask if you would be able to provide some assistance with, and input to my MSc thesis. It is titled "What's in a map? Communicating natural hazard information to stakeholders." I am particularly interested in the hazard of volcanic ash fall in New Zealand, and ways to add further value to the ash fall forecast maps distributed by GeoNet for different stakeholders. The thesis objectives are:

Determine what ash fall information various stakeholders need immediately following an eruption, and during the progress of the event, in order to make informed decisions.
Determine how to provide/display this information most effectively.
Use this information to design an ash fall forecast map.
Investigate what is required to achieve improved information output from the ash fall modeling program, as opposed to improved presentation.

This study uses literature and interviews with volcanic hazard and risk communication experts and stakeholders/endusers to design different ash fall forecast map styles, all of which could be produced from inputs from an ash fall model, such as ASHFALL. In addition, I plan to invite stakeholders/endusers, such as councils, CDEM, and lifeline and agriculture managers to participate in a survey exercise, during which I will present a hypothetical situation and then ask the respondents to critique the effectiveness of each map. Their responses will inform generic map design(s) which hopefully fulfils the critiques and criteria as best as possible.

I have been in contact with Gill Jolly and she has expressed her support for this project. This project has also received approval from the Department of Geological Sciences at the University of Canterbury, as well as the University of Canterbury Human Ethics Committee Low Risk Approval process. Given your expertise and experience in your position as [enter position here] I would like to discuss with you what makes an effective volcanic ashfall map and how it might be optimized for New Zealand stakeholders. To that end I would like to meet with you some time in the next couple of weeks to discuss this topic in depth. The meeting would last approximately one hour. I have attached a list of questions I would like to cover with you. I am able to travel to [Wellington/Taupo] to meet with you face to face. Alternatively, if you prefer, we could carry out the interview by Skype or telephone.

Thank you for your help and I look forward to hearing from you,

Nate Baird

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

College of Science

Department of Geological Sciences
Tel: +64 3 364 2700, Fax: +64 3 364 2769, Email: office@geol.canterbury.ac.nz

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Interview consent form

Project: What's in a map? Communicating natural hazard information to stakeholders
Student: Nathanael Baird
Nate.Baird@pg.canterbury.ac.nz
Supervisors: Tim Davies
Tim.Davies@canterbury.ac.nz
Erik Brogt
Erik.Brogt@canterbury.ac.nz
Tom Wilson
Thomas.Wilson@canterbury.ac.nz
Emma Hudson-Doyle
E.E.Hudson-Doyle@massey.ac.nz

The nature of and purpose for this interview has been fully explained to me. I have had the opportunity to ask questions which have been answered to my satisfaction. I am aware that this project has been approved by the department of geology at the University of Canterbury as well as the University of Canterbury Human Ethics Committee Low Risk Approval process. On this basis, I agree to participate in the interview part of the thesis.

I note that
- I can withdraw my consent and data at any time without penalty
- I am being asked for my professional opinion and not my personal view
- Data will be stored for a period of 2 years
- I am comfortable with being named in the thesis
- I am comfortable with my answers being included in the thesis

☐ I give permission for the interview to be audiotaped.

Name: ____

Date: ____

Appendix B
Ethics information for interviews with Stakeholders.

UNIVERSITY OF CANTERBURY HUMAN ETHICS COMMITTEE

APPLICATION FOR REVIEW & APPROVAL

This form should be completed in the light of the Principles and Guidelines issued by the Human Ethics Committee. Applicants must read those before filling out the application form. The latest versions of both the Guidelines and the Application Form can be found on the website of the Human Ethics Committee.
website: http://www.canterbury.ac.nzihumanethics

This application fmm is to be used for Applications <u>*NOT*</u> covered by the Educational Research Human Ethics Committee (ERHEC)

NOTE: This electronic copy may not have sufficient space for completion of all parts of the form if downloaded as a blank copy of the application form. It is intended as a template for use by those staff and students who have access to a word processor. When typing in please type where the paragraph marks start after each question, not in the actual boxes.

Please submit <u>SIX printed or typed copies</u> and <u>ONE electronic copy</u> of the completed application duly signed by applicant and supervisor or Head of Department, and all relevant documents referred to in questions 3, 7, 8, 9, 10, 11, 15 (i.e. authorizations, approvals, information and consent forms). Hard copies should be sent to the Secretary, Human Ethics Committee, Okeover House and electronic copies to human-ethics@canterbury.ac.nz.

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1. PROJECT NAME: What's in a map? Communicating natural hazard information to stakeholders

2. NAME OF APPLICANT: Nathanael Baird

   Contact Telephone No: 021 0220 0584

   UNIVERSITY DEPARTMENT (or other contact address): Geology

   EMAIL ADDRESS: nate.baird@pg.canterbury.ac.nz

   STATUS OF PROJECT (eg SOCI XYZ class project, M.A., M.Ed., M.Sc., Ph.D., Staff research study)
   M.Sc.

   NAME OF SUPERVISOR: Tim Davies

   OTHER INVESTIGATORS: Erik Brogt, Tom Wilson, and Emma H

   udson-Doyle (Massey University)

The checklist on the following page must be completed and signed by the applicant and, if the applicant is a student, by the applicant's supervisor

CHECKLIST

Please check the following items before sending the completed f01m to the Committee.

All the necessary signatures on page 1 have been obtained.	[X]
All the necessary approvals under Question 3 have been obtained or are the subject of correspondence of which copies are attached.	N/A
A copy of any questionnaire, with an appropriate rubric at the beginning or accompanied by an appropriate covering page, is attached.	N/A
A list of interview topics and, for a structured interview, a detailed list of questions, is attached.	[X]
A copy of any advertisement, or notice, or informative letter asking for volunteers is attached.	N/A
A copy of each information sheet required is attached.	[X]
A copy of each consent form required is attached.	[X]
A copy of the required debriefing sheet is attached.	N/A

Attention to the preceding check list is intended to ensure that the application and its documentation have been thoroughly reviewed by the applicant and (where applicable) by the supervisor and that the preparation of the project is up to the standard expected of and by the University of Canterbury.

The signature ofthe applicant will be understood to imply that the applicant has designed the project and prepared the application with due regard to the Principles and Guidelines of the HEC, that all the questions in the application form have been duly answered and that the necessary documentatio ·operly formulated and checked.

Signature of Applicant

The signature of the supervisor will be understood to imply in addition that, in the judgment of the supervisor, the design and documentation are of a standard appropriate for a research project carried out in the name of the University of Canterbury or for training in such research.

Signature of Supervisor

		Delete whichever is in-applicable
3 (a)	WILL THE PROJECT REQUIRE ETHICAL APPROVAL FROM OTHER BODIES? eg Health and Disability Ethics Committee (HDEC) If Yes, please explain how this approval has been or will be obtained, enclosing copies of relevant correspondence. *NOTE: To save time, it is recommended that in the case of HDEC applications, an application is made concurrently with the application to the UC HEC.*	**No**
(b)	WILL THE PROJECT REQUIRE APPROVAL FOR ACCESS TO THE PARTICIPANTS FROM OTHER INDIVIDUALS OR BODIES? (e.g., parents, guardians, school principals, teachers, boards, responsible authorities including employers, etc.) If Yes, please explain how this approval has been or will be obtained, enclosing copies of relevant correspondence.	**No**
(c)	WILL THE PROJECT REQUIRE MAORI CONSULTATION? If Yes, please provide evidence that consultation has occurred or, if underway, provide a copy of approval once gained.	**No**
(d)	WILL THE PROJECT REQUIRE COMMUNITY CONSULTATION? If Yes, please provide evidence of appropriate consultation.	**No**
4 (a)	IS THE PROJECT BEING EXTERNALLY FUNDED? If Yes, please identify the source of funds.	**No**
(b)	IS THE PROJECT COMMISSIONED BY OR CARRIED OUT ON BEHALF OF AN EXTERNAL BODY? If Yes, please identify the body and any Intellectual Property agreements. This includes ownership of data and reports arising.	**No**
(c)	IS THE PROJECT TO BE PART OF THE CEISMIC DIGITAL ARCHIVE? If so, please ensure all participants are made aware of this, and have filled in the UC CEISMIC Quake Studies consent form. See www.ceismic.org.nz.	**No**

Further, please ensure that all participants are made aware of any of the above in information sheets and consent forms provided.

A. DESCRIPTION OF THE PROJECT

Answer the following questions in language which is, as far as possible, comprehensible to lay people.

5 AIM

(a) What is the objective of the project?

The objective of this project is to determine what information lifeline managers, CDEM managers, etc. (hereafter referred to as stakeholders) need immediately following a volcanic eruption in order to make informed response decisions, and to determine how to provide/display this information most effectively.

(b) Describe the type of information sought.

I will be asking the participants for their opinions (personal and/or professional) on what information they need immediately following an eruption. I will also be asking them for their opinions on different map designs.

(c) Give the specific hypothesis, if any, to b~~e tested.~~

N/A

6 PROCEDURE

I will begin the interview by asking the participant questions regarding what information they wish to see on a volcanic ash fall forecast map. After I have finished the questions I will ask the participant to imagine that they are going about their daily work routine when they are informed that an eruption has occurred. I will then present the participant with several different ash fall forecast maps. I will have created all of the maps except for one. The map that was not created by me will be one which has been officially published by GNS. The participant will get one or two minutes with each map, after which they will be asked two write a sentence or two describing what information they were able to ascertain from it. After I have presented all of the maps I will ask several more questions relating to what the interviewee felt were the strengths and weaknesses of each map.

7 DOES THE PROJECT INVOLVE A QUESTIONNAIRE? **No**

If Yes, please attach a copy, if possible.

NOTE: The HEC does not normally approve a project which involves a questionnaire without seeing the questionnaire, although it may preview applications in some cases where the production of the questionnaire is delayed for good reason.

8 (a) DOES THE PROJECT INVOLVE A STRUCTURED INTERVIEW? **Yes**

If Yes, please list the topics to be covered and the questions to be used.

You can find the interview outline attached to this application

(b) DOES THE PROJECT INVOLVE AN UNSTRUCTURED INTERVIEW? **No**

If Yes, please list the range of topics likely to be discussed.

(c) IF THE PROJECT INVOLVES AN INTERVIEW OF EITHER TYPE, WILL IT BE RECORDED BY: AUDIO-TAPE **Yes No**

OR VIDEO-TAPE?

NOTE: This also covers focus groups.

(d) WILL THE PARTICIPANTS BE OFFERED THE OPPORTUNITY TO CHECK THE TRANSCRIPT OF THE INTERVIEW? **No**
This also covers focus groups.
NOTE: it is normal practice to have participants review their transcription. If this is not to be the case, please explain why you believe it is not necessary.
Participants should be informed of interview recording and transcription review.

No full transcripts will be written. The audio recordings serve only as a backup for the notes that are taken during the interview.

B. PARTICIPANTS

9 (a) WHO ARE THE PARTICIPANTS?
Various stakeholders throughout the North Island such as CDEM and lifeline managers

(b) HOW ARE THEY TO BE RECRUITED?
They will be sent an email inviting them to participate in this project. A copy of the email they will receive can be found attached to this application (the email will also be used to show what information will be provided to prospective participants).

(c) WILL ANY FORM OF INDUCEMENT BE OFFERED? **No**
If Yes, please give details and a brief justification.

(d) IF A SELECTION FROM A GROUP IS NECESSARY, HOW WILL IT BE MADE?
This will not be necessary.

(e) HOW MANY PARTICIPANTS (OF EACH CATEGORY, WHERE RELEVANT) DO YOU INTEND RECRUITING?
Between five and ten.

C. INFORMATION AND CONSENT

10. WHAT INFORMATION IS BEING GIVEN TO PROSPECTIVE PARTICIPANTS?
I will provide prospective participants with a brief summary explaining what my project is and why they have been invited to participate. A copy of the informational email can be found attached to this application (the email will also be used to show how prospective participants will be recruited).

NOTE: Projects which involve only an anonymous questionnaire may not necessarily require a separate information sheet, provided that the rubric of the questionnaire includes your name and contact number as well as the other points contained in the model shown in the Guidelines. In general, however, the HEC recommends that participants be given an information sheet, which they may retain, unless there are good reasons against such a procedure.

11 HOW IS INFORMED CONSENT TO BE OBTAINED?
(a) The research is strictly <u>anonymous</u>, an information sheet is supplied and informed consent is implied by voluntary participation in filling out a questionnaire (include a copy of the rubric for the questionnaire as in Appendix C of the Guidelines) **No**
This means you do not know the identity of any of the participants and will not include any personal participant details.

or	(b)	The research is not anonymous, but is confidential and informed consent will be obtained through a signed consent form (include a copy of the consent form and information sheet) *This means that while you do/may know the identity of the participants, with respect to the data provided, you will not make their identity public.* Where confidentiality is promised, what will be done to ensure that the identities of participants cannot be known by unauthorized persons? (e.g. use of pseudonyms and disguising of identifying material).	**No**
or	(c)	The research is neither anonymous nor confidential and informed consent will be obtained through a signed consent form (include a copy of the consent form and information sheet).	**Yes**
or	(d)	Informed consent will be obtained by so~~me other method – please specify and~~ provide details.	~~**No**~~

12 ARE THE PARTICIPANTS COMPETENT TO GIVE INFORMED CONSENT ON THEIR OWN BEHALF? **Yes**

NOTE: Children and young adults under the age of 16 years (or 18 years if still at school) require parental/caregiver consent as do adults with disabilities that limit comprehension and consent. Such participants should be provided with a suitable information sheet and an assent form where practicable.

If No, please explain:

(a) Why they are not competent to give informed consent on their own behalf.

(b) How consent will be obtained.

D RISK, DECEPTION, PRIVACY

13. WHERE WILL THE PROJECT BE CONDUCTED?
The interviews will be conducted at the participants' place of work.

14. FORESEEABLE RISKS TO THE PARTICIPANTS
If the answer to any of these questions is "Yes", please indicate briefly the nature of the risk and what actions you could take, or support mechanisms you could rely on, if a participant should become injured, distressed or offended while taking part in this project.
Support should not be undertaken by researcher. At the very least a list of support services should be included in the information sheet and also participants made aware of the possibility in the information sheet.

(a) Is there any risk to physical well-being? **No**

If yes describe processes in place:

(b) Could participation involve mental stress or emotional distress? **No**

If yes describe processes in place:

(c) Is there a possibility of giving moral or cultural offence? **No**

If Yes, describe processes in place and consultation/awareness undertaken:

15. IS DECEPTION INVOLVED AT ANY STAGE OF THE PROJECT? **No**

NOTE: The use in the information sheet or consent form or questionnaire of a title which differs from the project title given in this application form, in order not to reveal the real aim of the project, is considered to be a form of deception however mild.

If Yes, please

(a) Explain how and why it is to be used and how the participants will be 'debriefed' following their participation in the project.

(b) Attach a copy of the debriefing sheet prepared for use by the researcher or for distribution to the participants after ~~their participation in the project or~~ after the completion of the project.

16. WILL INFORMATION ABOUT THE SUBJECTS BE OBTAINED FROM THIRD PARTIES? **Yes**

This includes 'snowball' recruitment and also the accessing of potential participants via a third party.
In general third party contact information should not be given directly to the researcher – participants should contact the researcher and/or agree to be contacted.

If Yes, please state:

(a) The identity of the third party or parties.

Dr. Tom Wilson, a professor at the University of Canterbury and one of my supervisors

(b) Why such information is needed.

Due to his personal research and his position on a volcanic advisory board Dr. Wilson is well acquainted with some of the stakeholders and is able to direct me to which stakeholders are familiar enough with volcanic hazards to make these interviews as beneficial as possible.

(c) Whether appropriate consents for access to such information have been or will be obtained.

No consents will be necessary as Dr. Wilson will only be providing me with publicly available information.

(d) Whether the use of such data in your research project needs the consent of the participants.

Not applicable. No information other than publicly available contact information will be give.

NOTE: It may happen that by virtue of your job, you have right of access to information concerning the participants. Such information may have been given by the participants for a particular purpose or collated by yourself or colleagues in the normal course of your job. The use of such information for a quite different purpose (i.e., a research project culminating in some form of report) may well require that potential participants at least be informed that their agreement to participate may involve such use. The Information Privacy Principles should be consulted for guidance in this area.

F DATA STORAGE AND FUTURE USE

17 HOW WILL THE DATA BE STORED?

(a) Provide details of Where will the data with identifying information be securely stored?

All data will be stored on password-protected computers and locked folders on the university servers.

(b) Provide details of Where will the data with no identifying information be securely stored?

NOTE: All storage facilities should be locked and should be in rooms which can be locked.

All data will be stored on password-protected computers and locked folders on the university servers.

(c) Who, apart from the researcher and their supervisor (where applicable) will have authorised access to the data?

Note: Research Assistants and Transcribers need their own confidentiality forms and their participation needs to be made known to participants.

The only people authorized to access the raw data are those listed on the first page of this application.

(d) What will be done to ensure that unauthorised persons do not have access to the data?

All computers holding the data are password protected and university folders cannot be accessed by people who are not in the "group" as set by university IT services. Obtaining permission to be admitted to a group requires HoD signoff.

(e) What will happen to the raw data at the end of the project?

NOTE: up to MA level data is kept for 5 years and then destroyed; for above MA and staff research, it is normal practice to keep for 10 years and then destroyed. Participants need to be informed of and consent to what is decided.

Data will be stored for 5 years and then destroyed.

18 WHAT PLANS DO YOU HAVE FOR PUBLICATION OF THE DATA?

NOTE: Masters thesis and PhDs are public documents via the UC library database Also, participants should be offered summary of results

The results will be used in a master's thesis and therefore will be publicly available. In addition, scholarly articles from the research will be submitted for publication in peer-reviewed journals.

19 ARE THERE PLANS FOR FUTURE USE OF THE DATA BEYOND THOSE

No

ALREADY DESCRIBED?

If Yes, please describe the future use.

Nate Baird
Department of Geological Sciences
Tel: +64 021 0220 0584
Email: nate.baird@pg.canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Dear [enter name here],

My name is Nate Baird and I am a Masters thesis student at the University of Canterbury in the hazard and disaster management program, supervised by Tim Davies, Erik Brogt, Tom Wilson (all from the University of Canterbury) and Emma Hudson-Doyle (JCDR, Massey University). I am writing to ask if you would be able to provide some assistance with, and input to my MSc thesis. It is titled "What's in a map? Communicating natural hazard information to stakeholders." I am particularly interested in the hazard of volcanic ash fall in New Zealand, and ways to add further value to the ash fall forecast maps distributed by GeoNet for different stakeholders. The thesis objectives are:

Determine what ash fall information various stakeholders need immediately following an eruption, and during the progress of the event, in order to make informed decisions.
Determine how to provide/display this information most effectively.
Use this information to design an ash fall forecast map.
Investigate what is required to achieve improved information output from the ash fall modeling program, as opposed to improved presentation.

This study uses literature and interviews with volcanic hazard and risk communication experts and stakeholders/endusers to design different ash fall forecast map styles, all of which could be produced from inputs from an ash fall model, such as ASHFALL. In addition, I plan to invite stakeholders/endusers, such as councils, CDEM, and lifeline and agriculture managers to participate in a survey exercise, during which I will present a hypothetical situation and then ask the respondents to critique the effectiveness of each map. Their responses will inform generic map design(s) which hopefully fulfils the critiques and criteria as best as possible.

This project has received approval from the Department of Geological Sciences at the University of Canterbury, as well as the University of Canterbury Human Ethics Committee Low Risk Approval process. Given your expertise and experience in your position as [enter position here] I would like to discuss with you what information is pertinent immediately following a volcanic eruption, what makes an effective volcanic ash fall map, and how it might be optimized for New Zealand stakeholders. To that end I would like to meet with you some time in the next several weeks to discuss this topic in depth. The meeting would last approximately one hour. I have attached a list of questions I would like to cover with you. I am able to travel to [enter location of office here] to meet with you face to face. Alternatively, if you prefer, we could carry out the interview by Skype.

Thank you for your help and I look forward to hearing from you,

Nate Baird

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

College of Science
Department of Geological Sciences
Tel: +64 3 364 2700, Fax: +64 3 364 2769, Email: office@geol.canterbury.ac.nz

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Interview consent form

Project: What's in a map? Communicating natural hazard information to stakeholders
Student: Nathanael Baird
Nate.Baird@pg.canterbury.ac.nz
Supervisors: Tim Davies
Tim.Davies@canterbury.ac.nz
Erik Brogt
Erik.Brogt@canterbury.ac.nz
Tom Wilson
Thomas.Wilson@canterbury.ac.nz
Emma Hudson-Doyle
E.E.Hudson-Doyle@massey.ac.nz

The nature of and purpose for this interview has been fully explained to me. I have had the opportunity to ask questions which have been answered to my satisfaction. I am aware that this project has been approved by the department of geology at the University of Canterbury as well as the University of Canterbury Human Ethics Committee Approval process. On this basis, I agree to participate in the interview part of the thesis.

I note that
- I can withdraw my consent and data at any time without penalty
- Data will be stored for a period of 5 years
- I am comfortable with being named in the thesis
- I am comfortable with my answers being included in the thesis

☐ I give permission for the interview to be audiotaped.

Name: ____

Date: ____

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2013/107

23 August 2013

Nathanael Baird
Department of Geology
UNIVERSITY OF
CANTERBURY

Dear Nathanael

The Human Ethics Committee advises that your research proposal "What's in a map? Communicating natural hazard information to stakeholders" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 23 August 2013.

Best wishes for

your project.

Yours sincerely

Lindsey MacDonald
Chair
University of Canterbury Human Ethics Committee

Appendix C
Ethics information for the survey.

FOR STUDENT RESEARCH UP TO AND INCLUDING MASTERS LEVEL

ETHICAL APPROVAL OF LOW RISK RESEARCH INVOLVING HUMAN PARTICIPANTS REVIEWED BY DEPARTMENTS

Please read the important notes appended to this form before completing the sections below

1 RESEARCHER'S NAME: Nathanael Baird

2 NAME OF DEPARTMENT OR SCHOOL: Geology

3 EMAIL ADDRESS: nate.baird@pg.canterbury.ac.nz

4 TITLE OF PROJECT: What's in a map? Communicating natural hazard information to stakeholders

5 PROJECTED START DATE OF PROJECT: 1 March, 2013

6 STAFF MEMBER/SUPERVISOR RESPONSIBLE FOR PROJECT: Tim Davies

7 NAMES OF OTHER PARTICIPATING STAFF AND STUDENTS: Erik Brogt and Thomas Wilson

8 STATUS OF RESEARCH: (e.g. class project, thesis) Thesis

9 BRIEF DESCRIPTION OF THE PROJECT:
Please give a brief summary (approx. 300 words) of the nature of the proposal in lay language, including the aims/objectives/hypotheses of the project, rationale, participant description, and procedures/methods of the project: The aim of my thesis is to determine what makes an effective short-term natural hazard map. I have chosen to focus specifically on volcanic ashfall. I am investigating what map elements and display styles are most effective at communicating the necessary information for stakeholders (people such as members of civil defence and emergency managers for companies that deal with lifelines such as power lines and sewage) to be able to fulfil their responsibilities. To accomplish this I have conducted an extensive literature review, interviewed members of the GNS volcanology team, and interviewed a small group of selected stakeholders (both sets of interviews had their own ethics committee application which was approved). I am now in the final stage of my data collection, which consists of sending a survey to all pertinent stakeholders, asking for input on the maps that I have created. It is for this survey that I am seeking approval from the ethics committee. The information gathered will be kept anonymous, and at no point in the survey will the participants be asked to provide personal information. You can find a copy of the survey attached to this application. The survey will be sent out via email. The email addresses will come from a variety of sources. My supervisors have previously collaborated with pertinent stakeholders and will provide me with their contact information. Also, many of the stakeholders I interviewed in an earlier stage of my research have told me that they are happy to participate in the survey portion as well, and that they will also pass the survey on to anyone they work with who they think might be of interest. I will also obtain contact information be searching the public directories of pertinent groups and businesses.

10 WHY IS THIS A LOW RISK APPLICATION?

Description should include issues raised in the Low Risk Checklist.
Please give details of any ethical issues which were identified during the consideration of the proposal and the way in which these issues were dealt with or resolved.
This is a low risk application because no personal data will be asked of the respondents, keeping everything completely anonymous. Also, I do not anticipate participation in the survey causing any mental or psychological harm or stress.

11 PROVIDE COPIES OF INFORMATION & CONSENT FORMS FOR PARTICIPANTS
These forms should be on University of Canterbury Departmental letterhead. The name of the project, name(s) of researcher(s), contact details of researchers and the supervisor, names of who has access to the data, the length of time the data is to be stored, that participants have the right to withdraw participation and data provided without penalty, and what the data will be used for should all be clearly stated. A statement that the project has been reviewed approved by the appropriate department and the University of Canterbury Human Ethics Committee Low Risk Approval process should also be included.

Please find the informational sheet and consent form attached. The forms provided do not contain the departmental letterhead because the text has been copied off of the survey. Since the survey is being hosted online through the university's access to Qualtrics, the survey will contain the logo of the university on every page. On the page for the consent form, users will be forced to either select 'yes' or 'no'. If they choose 'no' they are sent directly to the final page of the survey which thanks them for their time.

What's in a map? Communicating natural hazard information to stakeholders

Information sheet for survey responders

My name is Nate Baird and I am a Masters thesis student at the University of Canterbury in the hazard and disaster management program, supervised by Tim Davies, Erik Brogt, Tom Wilson (all from the University of Canterbury) and Emma Hudson-Doyle (JCDR, Massey University). I would appreciate it if you would be willing to provide some assistance with, and input to my MSc thesis. It is titled "What's in a map? Communicating natural hazard information to stakeholders." I am particularly interested in the hazard of volcanic ash fall in New Zealand, and ways to add further value to the ash fall forecast maps distributed by GeoNet for different stakeholders. The thesis objectives are:

Determine what ash fall information various stakeholders need immediately following an eruption, and during the progress of the event, in order to make informed decisions.
Determine how to provide/display this information most effectively.
Use this information to design an ashfall forecast map.

This study uses literature and interviews with volcanic hazard and risk communication experts and stakeholders/endusers to design different ash fall forecast map styles, all of which could be produced from inputs from an ash fall model, such as ASHFALL. Given your expertise and experience in your position I would like to ask you to participate in this project by completing this survey, in which you will answer questions regarding what information you feel is pertinent immediately following a volcanic eruption, what makes an effective volcanic ashfall map, and how it might be optimized for New Zealand stakeholders.

I foresee no potential risks, physical or psychological, associated with the completion of this survey.

If you desire, you may receive a copy of the project results by contacting me at the conclusion of the project.

Participation is voluntary and you have the right to withdraw at any stage without penalty. If you choose to withdraw, simply close out of the browser window before completing the survey. All incomplete surveys will be disregarded.

The results of this project will be made publicly available as part of an MSc thesis. Certain responses to the survey may be used in the thesis, but the sources of the responses will be kept anonymous. The results of the survey will be stored for five years on password protected computers and servers to which only myself and my supervisors will have access. Additional people can only be granted access under approval from the head of department for Geological Sciences. After five years the data will be destroyed.

This project has been reviewed and approved by Department of Geological Sciences at the University of Canterbury as well as the University of Canterbury Human

Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz). If you have any questions or concerns about the project you are welcome to contact myself or one of my supervisors (whose email address can be found below) and we would be pleased to discuss them with you.

Thank you for your help,
Nate Baird nate.baird@pg.canterbury.ac.nz

Tim Davies: tim.davies@canterbury.ac.nz
Erik Brogt: erik.brogt@canterbury.ac.nz
Tom Wilson: thomas.wilson@canterbury.ac.nz
Emma Hudson-Doyle: e.e.hudson-doyle@massey.ac.nz

What's in a map? Communicating natural hazard information to stakeholders

Survey consent form

The nature of and purpose for this survey has been fully explained to me. I have had the opportunity to ask questions which have been answered to my satisfaction. I am aware that this project has been approved by the Department of Geological Sciences at the University of Canterbury as well as the University of Canterbury Human Ethics Committee Low Risk Approval process. On this basis, I agree to participate in the survey part of the thesis.
I understand that

- My responses will be kept anonymous
- I can withdraw my consent and terminate the survey before completion without penalty
- Data will be stored securely on password protected computers and servers for a period of 5 years, after which it will be destroyed
- I am able to receive a report on the findings of the study by contacting the researcher
- I am comfortable with my answers being included in an MSc thesis
- I can contact the researcher or his supervisors for further information
- GNS Science is not bound to adhere to the findings of this study

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Ref: HEC 2013/95/LR

13 December 2013

Nathanael Baird
Department of Geography
UNIVERSITY OF
CANTERBURY

Dear Nathanael

Thank you for forwarding your Human Ethics Committee Low Risk application for your research proposal "What is in a map? Communicating natural hazard information to stakeholders".

I am pleased to advise that this application has been reviewed and I confirm support of the Department's approval for this project.

With best wishes for

your project. Yours

sincerely

Lindsey MacDonald
Chair, Human Ethics Committee

Appendix D
Interview questions for scientists at GNS. There are 3 different sets of questions due to the participants' different roles at GNS.

GENERAL

1. Can you tell me about your role in the generation of the ash fall hazard maps?
2. What do you think are the limitations of the current maps? And the positives?
3. What are the main things you would like to change in these maps, if possible?

SPECIFIC QUESTIONS ABOUT GEONET ASHFALL FORECAST MAPS

4. How do you think stakeholders feel about the effectiveness of the current ash fall hazard maps used by GeoNet? For example, emergency managers, police, regional councils, etc. How about the general population?
5. How do you think people feel about the amount of information provided? How about the level of detail?
6. What information are people most interested in obtaining from the maps?
7. How do you feel about producing several different maps (be it a simple one that comes out quickly and a more detailed one that comes later, different maps showing different infrastructure, or different model options)?
8. What are your thoughts on providing stakeholders with specific information concerning how much of their property will be affected with regards to exposure (e.g. how many kms of power lines) and/or fragility (e.g. what the consequences/impact will be)?
9. What are your thoughts on delaying the publication of the map to stakeholders for several minutes in order to include more information in it? (if we use a GIS program to enhance the ASHFALL output it may take a few minutes)
10. Have people asked about how much time they can expect before the ash begins to reach them?
11. How understanding are people of the limitations of GeoNet's products, such as ash fall maps?
12. Have people expressed concern about the confidence GNS/GeoNet has in the hazard map (e.g. there is an 80% probability that this is how the ash will be deposited)? Please describe.
    12.1. How do you feel about having the confidence level clearly labelled on the map?
13. What do you think is the best way to communicate the uncertainty inherent in a modeled forecast?
14. What is your opinion on marking hazard zones rather than ash fall depths?
15. What is your opinion on marking areas that will not be affected by the ash fall?
    15.1. What do you think are the limitations of not specifically marking unaffected areas?
16. How do you think people would respond to a probabilistic hazard map (if possible)?

IF THERE IS TIME

17. How do you think people feel about having the direction of the wind on the map?

GENERAL

1. What do you think are the limitations of the current ash fall forecast maps? What about the positives?
2. What are the main things you would like to change in these maps, if possible?
3. How do you think stakeholders feel about the effectiveness of the current ash fall maps? How about the general population?
4. What information are people most interested in obtaining from the maps?

SPECIFIC QUESTIONS ABOUT GEONET ASHFALL FORECAST MAPS

5. What is your opinion on marking hazard zones as opposed to ash fall depths on GeoNet ash fall hazard maps?
6. What are your thoughts on how the ash fall hazard zone is currently marked, with a single graduated colour? Do you think there is a better option? If so, what would you suggest?
7. What are your thoughts on having colour on the map?
8. What do you think would be the most effective base map?
9. What do you think should be displayed on the base map?
10. What are your thoughts on creating several different maps which contain different information, such as one for vector which shows the gas lines, one for the power companies which shows the power lines, etc.?
    10.1. Maybe if we put all of the information together onto a google earth file and that way people can turn different layers on and off and only see what they want to? This also allows them to type in a specific address and see how that location is being affected.
11. What are your thoughts on providing stakeholders with specific information concerning how much of their property will be affected with regards to exposure (e.g. how many kms of power lines) and/or fragility (e.g. what the consequences/impact will be)?
12. One thing that must be communicated with every piece of information is the level of uncertainty associated with it. What do you think is the best way to accomplish this?
13. Which do you feel is more important, keeping the map zoomed far out so as to give the overall view (e.g. currently, even a small eruption on the north island is placed on a map that shows the whole north island), or pull the map in closer to better show exactly what areas are affected (reference vs resolution)? Is the map purposely left so far out in order to increase the inherent uncertainty and avoid having to list specific locations?
14. What are your thoughts on producing several time-dependent maps which show how the ash depths will change with time (if possible)? Do you think it would be beneficial, or computationally too ‘expensive’?
15. Can we import the data into a GIS which already has information such as roads, power lines, populations, etc. loaded into it? If so, what are your thoughts on providing a table along with the map which lists how much of each category will be affected?
16. Seeing as large amounts of post-processing in a GIS would require at least a small amount of time, how do you feel about the idea of having two maps created, one

with minimal information which is published immediately and another with more information which is published a few minutes later after the processing is complete?

17. What are your thoughts on the generation, use, and effectiveness of probabilistic hazard maps?
18. How do you think people would respond to a probabilistic hazard map (if possible)?
19. What are your thoughts on making the map based in google earth with layers that you can turn on and off?

IF THERE IS TIME

20. How do you think people feel about having the direction of the wind on the map?
21. What are your thoughts on providing stakeholders with specific information concerning how much of their property will be affected with regards to exposure (e.g. how many kms of power lines) and/or fragility (e.g. what the consequences/impact will be)?
22. How do you feel about producing several different maps (e.g. a simple one that comes out quickly and a more detailed one that comes later, different maps showing different infrastructure, or different model options)?
23. What is your opinion on marking areas that will not be affected by the ash fall?

GENERAL

1. What do you think are the limitations of the current ash fall forecast maps? What about the positives?
2. What are the main things you would like to change in these maps, if possible?
3. What is your opinion on marking hazard zones as opposed to ash fall depths?
4. How understanding are people of the limitations of GeoNet's products, such as ash fall maps?

SPECIFIC QUESTIONS ABOUT GEONET ASHFALL FORECAST MAPS

5. What level of certainty is attached to the modeled ash deposition? Please describe.
6. What are your thoughts on having the confidence level clearly labelled on the map?
    6.1. How do you think people will interpret and utilize this confidence level, if at all?
7. How detailed / high resolution can the map get before we reach a point where there is not enough confidence in the accuracy of the model to say where the ash will fall?
8. If we wanted to create an interactive tool with the ash fall map where people could enter an address and see how that location is affected, would we have to use graduated color(s) with a feathered edge due to accuracy limitations?
9. What do you think is the best way to communicate the uncertainty inherent in a modeled forecast?
10. If we run ASHFALL twice with the same set of numbers, would it give us slightly different results (i.e. is there a part of the program which randomly selects a value from within a range), or would it be the exact same?

10.1. If the results are slightly different, would it be practical (with regards to time and effort) to run the program numerous times and find a way to perform a type of monte carlo assessment on the output?

11. How difficult (with regards to both time and effort) is it to create new .BLN files for things such as power lines, power substations, gas pipes, local water supplies, etc.? How many of these files already exist?
12. Can the base map .BLN file be changed to something more complicated such as a shaded relief DEM, or a black and white aerial photo, or does it need to remain something simple?
13. How much would it slow down the run time of the program if you included 5 or 10 .BLN files?
14. Has the SURFER package been updated to allow for different colors on different .BLN files?
15. Is the .GRD file able to be displayed in multiple colors (to show different ash depths)?
16. ASHFALL calculates where the ash is by taking specific time segments and calculating where the particles will be at the end of each segment. Can we have the program give us a printout of every time segment (or every 5, or 10, etc.)?
17. Am I correct in my belief that the produced .GRD file is able to be read by a GIS program? If so, would post-processing to perform actions such as creating depth bands based on the .GRD file values or creating a table of calculated amounts of affected infrastructure in each depth band be able to be fully automated?
    17.1 How long would it take for a fully automated system to perform such actions?

IF THERE IS TIME

18. How do you think people feel about having the direction of the wind on the map?
19. Have people asked about the expected time until the ash reaches them? If yes, please describe.
20. What are your thoughts on providing stakeholders with specific information concerning how much of their property will be affected with regards to exposure (e.g. how many kms of power lines) and/or fragility (e.g. what the consequences/impact will be)?
21. What are your thoughts on delaying the publication of the map to stakeholders for several minutes in order to include more information in it? (if we use a GIS program to enhance the ASHFALL output it may take a few minutes)
22. How do you feel about producing several different maps (e.g. a simple one that comes out quickly and a more detailed one that comes later, different maps showing different infrastructure, or different model options)?
23. How do you think people would respond to a probabilistic hazard map (if possible)?
24. What is your opinion on marking areas that will not be affected by the ash fall?
    24.1. What do you think are the limitations of not specifically marking unaffected areas?

Appendix E
Questions for the stakeholders.

1. What position do you hold?
2. What are your responsibilities in the event of a volcanic eruption?
3. What information regarding the deposition of volcanic ash would you need to adequately fulfil those responsibilities?
4. How familiar are you with the ash fall forecast map that GNS publishes?
   -show an example of one
   4.1. Have you used one before? If so, what were the pros and cons of the map in your experience?
   4.2. Do you know how to access this map in the event of an eruption?
5. What are your initial thoughts upon looking at this map?
6. Do you feel like it is missing any important pieces of information? If so, what?
7. Do you feel like there is any information on there that is not necessary? If so, what?
8. Is there anything you would like to change in the map?
9. Would you be interested in having GNS supply you with information regarding the extent to which your assets which will be exposed to ash deposition? How about information regarding the fragility of your assets?
   9.1. Would you have concerns about the information regarding the location and quantity of your assets being made readily available to the public?
   9.2. What are your thoughts on being provided with a KML file which you can download and use in your own system?
10. What are your thoughts on not receiving a map for a while, possibly up to several hours, in exchange for a more accurate model?
11. What are your thoughts on receiving an ash fall map before an eruption has occurred, with the understanding that there will be a very high level of uncertainty associated with it?
12. Does your company/agency conduct its own information gathering concerning the exposure of your assets, such as measuring ash thicknesses and/or determining exact boundaries of affected areas? Do you share this information with GNS? If not, would you be willing to?

Assessment of maps

Imagine that it is a normal workday. As you are working, an email arrives alerting you to an eruption at Mount Tongariro and informing you that you will soon receive more information from GNS. After 10 minutes have gone by you receive an alert from GNS which provides you with several maps. You have not received any information about the status of your assets and therefore must determine the impact of the ash and what actions need to be taken from the maps provided. For each map please study it for a moment and then write a sentence or two describing what information you are able to obtain from it and what decisions you are able to make based on this information.

Show the maps one at a time, changing the order for each interviewee. Only give them a minute or two with a map, then once they are done writing their response give them the next one. Once finished with all of them, lay them out side by side for comparison.

Now that we have finished, let's critique them.

13. What where the a) strengths and b) weaknesses of
    Map 1?
    Map 2?
    Map 3?
14. Talk me through how you would use one of these maps to meet your responsibilities following an eruption.
15. Which map do you prefer and why?
16. What would you change about your preferred map?
17. How much trust do you place in the accuracy of these maps? Or in other words, how detrimental would it be if the map showed you close to the boundary but not receiving any ash, but then you actually do receive some?
    17.1. How about if the map showed you receiving 1 mm of ash but you actually received 15 mm?

Appendix F
Survey questions and answers.

2. Do you have experience managing a natural hazard event in a professional setting?

#	Answer		Response	%
1	Yes		23	64%
2	No		13	36%
	Total		36	100%

3. Please select the option which best describes your sector.

#	Answer		Response	%
1	Emergency management		18	49%
2	Infrastructure / Lifelines		5	14%
3	Primary industries		0	0%
4	Health		2	5%
5	Private business		3	8%
6	Scientist		5	14%
7	Other (please describe)		4	11%
	Total		37	100%

4. What information regarding the deposition of the erupted volcanic ash would you need to know to adequately fulfill your professional responsibilities immediately following an eruption that is likely to deposit ash in your area?

#	Question	This information is unnecessary	Helps to know, but not necessary	This information is necessary	Total Responses	Mean
1	Depth of ash expected for your area	0	3	33	36	2.92
2	Amount of time until arrival of ash	0	5	30	35	2.86
3	Chemical properties of the ash	1	15	20	36	2.53
4	The duration of time for which you will be experiencing continuous deposition	0	5	30	35	2.86
5	Total volume of ash erupted	5	23	7	35	2.06
6	Spatial extent that will experience ashfall	0	4	32	36	2.89
7	Eruption column height	4	28	4	36	2.00

5. A hazard map which contains more accurate spatial and temporal extents of ash fall would require a longer processing time by the modelling program. How long after the start of an eruption would you be comfortable waiting for a more accurate hazard map to arrive?

#	Answer		Response	%
1	None, I need the map as soon as possible		10	28%
2	20 minutes		7	19%
3	40 minutes		4	11%
4	1 hour		8	22%
5	2 hours		4	11%
6	More than 2 hours		3	8%
	Total		36	100%

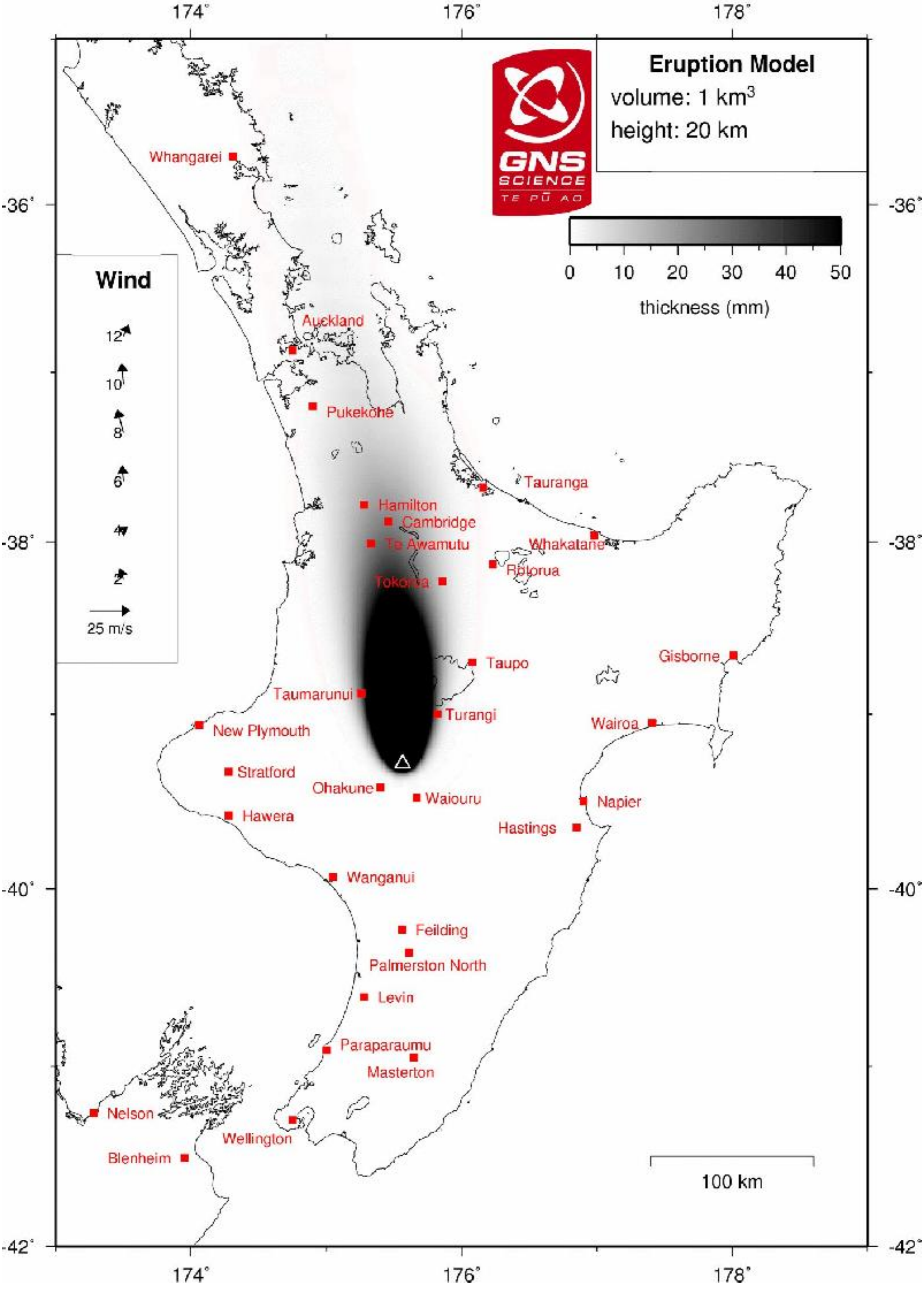
6. If GNS were to provide you with a file of the forecasted ash deposition for you to input into your own system to analyse, what format would you like the file to come in (you may select more than one if there is no preference or extra benefit between the options)?

#	Answer		Response	%
1	Shapefile		20	56%
2	Google Earth file		23	64%
3	Other		5	14%

Other
tab file (map info table)
MapInfo TAB or WFS
ArcGIS geodatabase
MapInfo preferred, but we can convert from Shapefile
WOULD NEED TO TEST THE FORMAT

PREDICTED ASHFALL AREA

For a Ruapehu eruption at 1800 Thursday 05 September 2013



7. Where is the ash likely to be deposited (approximately)?

#	Answer		Response	%
1	North		35	97%
2	East		0	0%
3	South		1	3%
4	West		0	0%
	Total		36	100%

8. Which town(s) are forecasted to receive ash deposition? (Select all that apply)

#	Answer		Response	%
1	Whangarei		3	8%
2	Auckland		13	36%
3	Pukekohe		15	42%
4	Tauranga		2	6%
5	Hamilton		34	94%
6	Cambridge		35	97%
7	Whakatane		0	0%
8	Te Awamutu		34	94%
9	Rotorua		0	0%
10	Tokoroa		28	78%
11	Gisborne		0	0%
12	Taupo		4	11%
13	Taumarunui		35	97%
14	Turangi		35	97%
15	Wairoa		0	0%
16	New Plymouth		0	0%
17	Stratford		0	0%
18	Ohakune		0	0%
19	Waiouru		0	0%
20	Napier		0	0%
21	Hastings		0	0%
22	Hawera		0	0%
23	Wanganui		0	0%
24	Other		2	6%

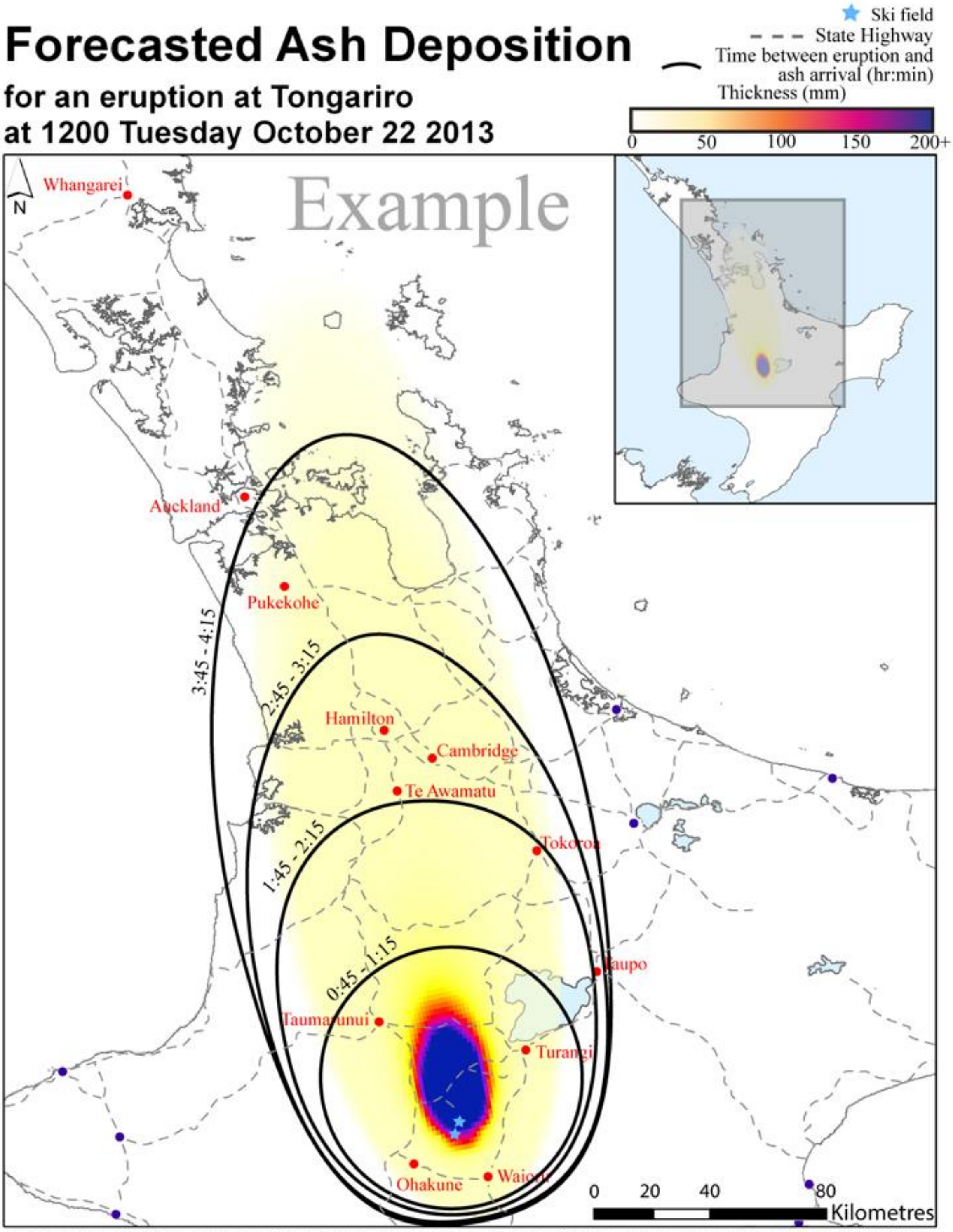
Other
Tokoroa
Scanned map detail not clear, Pukekphe may recieve light fall.

9. Is the wind data used on this map the current conditions, or the historical average?

#	Answer		Response	%
1	Current conditions		13	37%
2	Historical average		1	3%
3	Unable to determine		21	60%
	Total		35	100%

10. Does this map account for forecasted changes in wind conditions?

#	Answer		Response	%
1	Yes		2	6%
2	No		16	44%
3	Unable to determine		18	50%
	Total		36	100%



For more in-depth information regarding the impacts of volcanic ash deposition (how to prepare yourself for it and what to do during it) please visit http://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/Eruption!-What-to-do

This is a model of how the ash will be deposited on the ground at the end of the event. For information concerning how the ash will interact with air currents and how this will affect air travel please visit http://www.caa.govt.nz/meteorology/Volcanic_Ash_Advisory_System.htm

Disclaimer: This forecast has been created using estimated values. It is possible that the ash will be deposited in a different manner than is depicted here. This forecast is supplied only as an aid for decision making and as such the issuing organisation bears no responsibility for any decisions made based upon this forecast.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Auckland	5-15	4:00 – 4:30
Cambridge	15-45	2:00 – 2:30
Hamilton	15-45	2:15 – 2:45
Ohakune	15-45	0:15 – 0:45
Pukekohe	5-25	3:15 – 3:45
Taumarunui	35-75	0:15 – 0:45
Taupo	0-2	1:15 – 1:45
Te Awamatu	20-50	2:00 – 2:30
Tokoroa	5-30	1:30 – 2:00
Turangi	25-65	0:15 – 0:45
Waioru	20-50	0:15 – 0:45
Whangarei	0-2	6:15 – 6:45

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs of residential homes may begin to sag or collapse under the weight of the ash (long-span roofs may begin to suffer damage before this point). It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

11. Where is the ash likely to be deposited (approximately)?

#	Answer		Response	%
1	North		36	100%
2	East		0	0%
3	South		0	0%
4	West		0	0%
	Total		36	100%

12. Which town(s) are forecasted to receive ash deposition? (Select all that apply)

#	Answer		Response	%
1	Whangarei		14	39%
2	Auckland		26	72%
3	Pukekohe		36	100%
4	Tauranga		1	3%
5	Hamilton		36	100%
6	Cambridge		35	97%
7	Whakatane		2	6%
8	Te Awamutu		35	97%
9	Rotorua		2	6%
10	Tokoroa		31	86%
11	Gisborne		0	0%
12	Taupo		22	61%
13	Taumarunui		34	94%
14	Turangi		35	97%
15	Wairoa		6	17%
16	New Plymouth		0	0%
17	Stratford		0	0%
18	Ohakune		34	94%
19	Waiouru		29	81%
20	Napier		0	0%
21	Hastings		0	0%
22	Hawera		0	0%
23	Wanganui		0	0%
24	Other		0	0%

Other

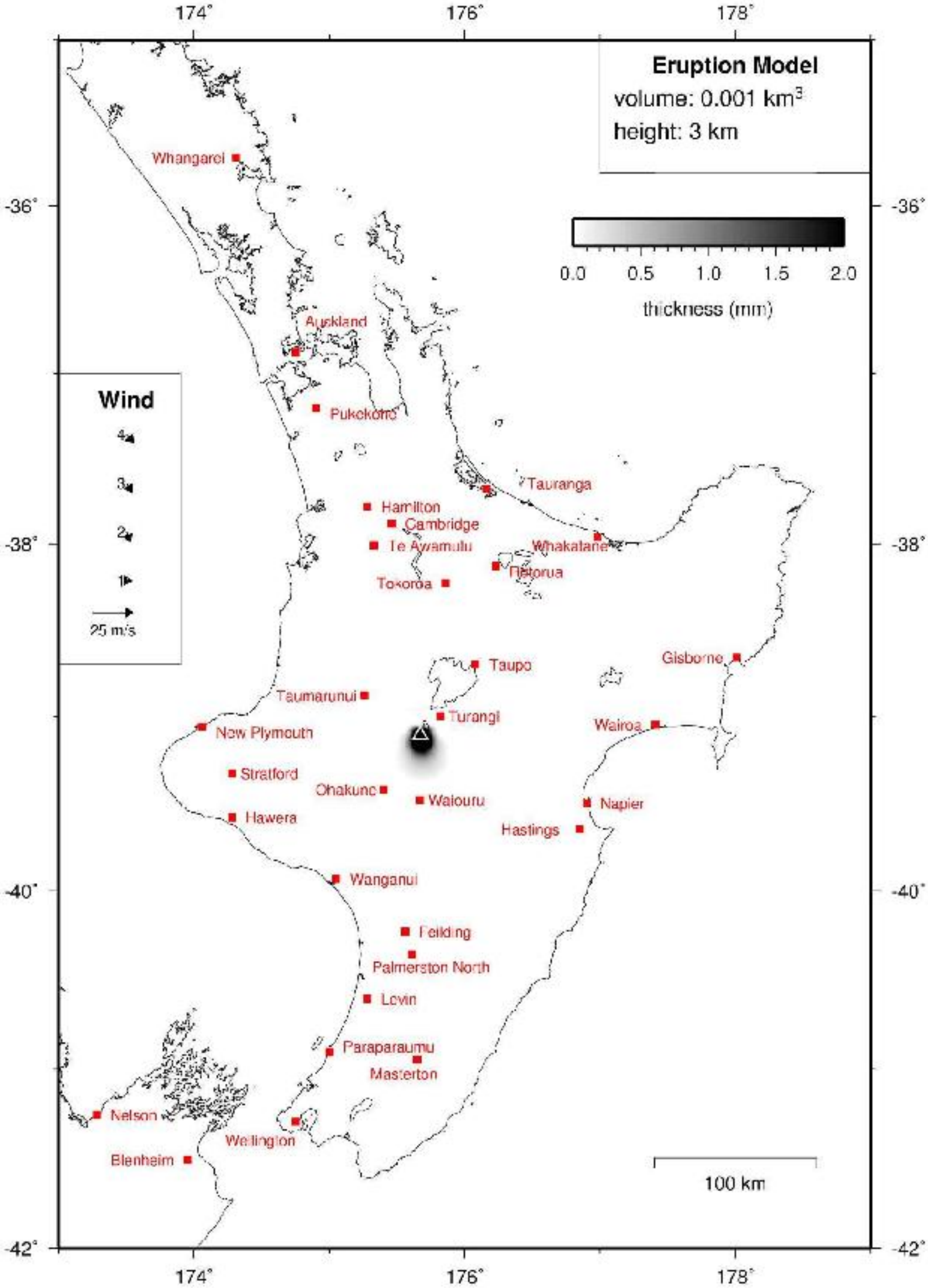
13. Is the wind data used on this map based on current conditions or the historical average?

#	Answer		Response	%
1	Current conditions		25	69%
2	Historical average		4	11%
3	Unable to determine		7	19%
	Total		36	100%

14. Does this map account for forecasted changes in wind conditions?

#	Answer		Response	%
1	Yes		20	56%
2	No		6	17%
3	Unable to determine		10	28%
	Total		36	100%

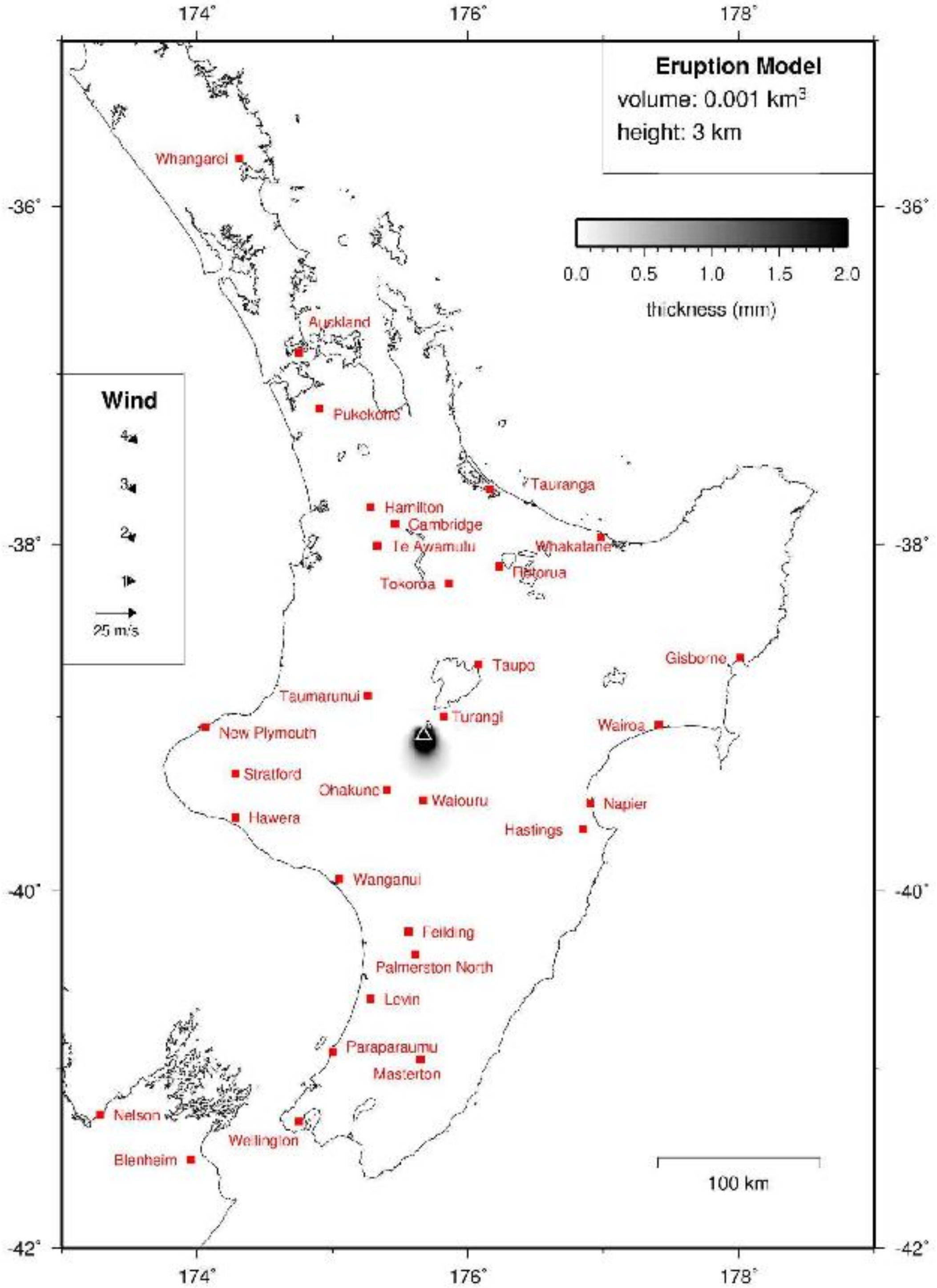
PREDICTED ASHFALL AREA
For a Tongariro eruption at 1200 Tuesday 07 August 2012



15. Is there any information on the map which you feel is not necessary?(select all that apply)

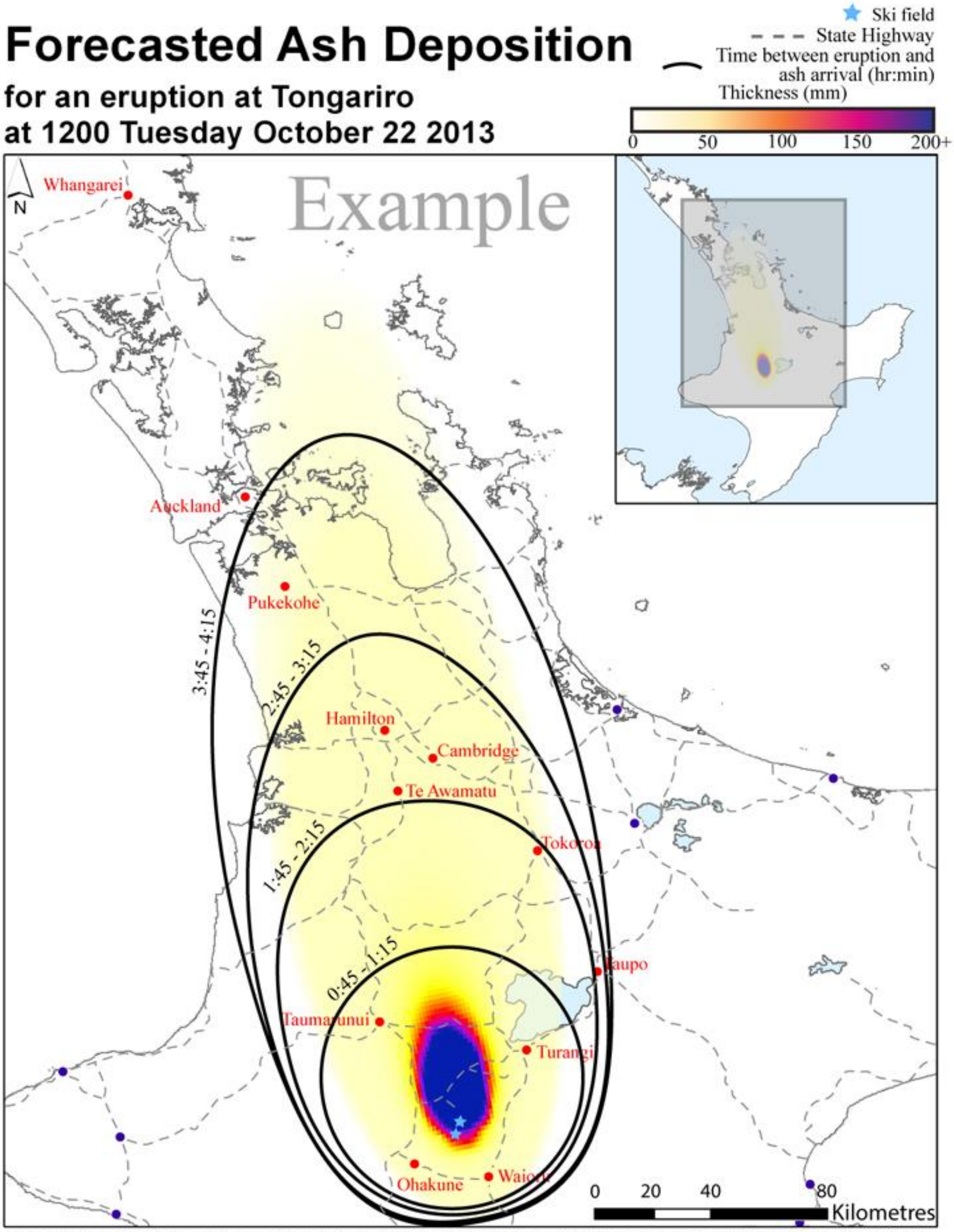
#	Answer		Response	%
1	Graticule (longitude and latitude markings)		15	83%
2	City and town names		3	17%
3	City and town locations		3	17%
4	Wind data		6	33%
5	Vent location symbol		3	17%
6	Scale bar		4	22%
7	Ash depth scale bar		2	11%
8	Date and time of eruption		2	11%
9	Eruption volume		5	28%
10	Eruption height		4	22%
11	Other		4	22%

PREDICTED ASHFALL AREA
For a Tongariro eruption at 1200 Tuesday 07 August 2012



16. Based on viewing this map, how much trust do you place in the accuracy of it?

#	Answer		Response	%
1	I expect the ash deposition to match the map		1	3%
2	I expect some variability, but I assume that the ash deposition will be similar to the map		11	32%
3	I believe the map to be a best estimate and that there is the potential for the ash to be deposited differently than how it is shown on the map		21	62%
4	I believe that the map shows one possible pattern of deposition, but that it is likely that the ash will be deposited in a different manner than how it is shown on the map		1	3%
	Total		34	100%



For more in-depth information regarding the impacts of volcanic ash deposition (how to prepare yourself for it and what to do during it) please visit http://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/Eruption!-What-to-do

This is a model of how the ash will be deposited on the ground at the end of the event. For information concerning how the ash will interact with air currents and how this will affect air travel please visit http://www.caa.govt.nz/meteorology/Volcanic_Ash_Advisory_System.htm

Disclaimer: This forecast has been created using estimated values. It is possible that the ash will be deposited in a different manner than is depicted here. This forecast is supplied only as an aid for decision making and as such the issuing organisation bears no responsibility for any decisions made based upon this forecast.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Auckland	5-15	4:00 – 4:30
Cambridge	15-45	2:00 – 2:30
Hamilton	15-45	2:15 – 2:45
Ohakune	15-45	0:15 – 0:45
Pukekohe	5-25	3:15 – 3:45
Taumarunui	35-75	0:15 – 0:45
Taupo	0-2	1:15 – 1:45
Te Awamatu	20-50	2:00 – 2:30
Tokoroa	5-30	1:30 – 2:00
Turangi	25-65	0:15 – 0:45
Waioru	20-50	0:15 – 0:45
Whangarei	0-2	6:15 – 6:45

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs of residential homes may begin to sag or collapse under the weight of the ash (long-span roofs may begin to suffer damage before this point). It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

17. Please critique each aspect of the map

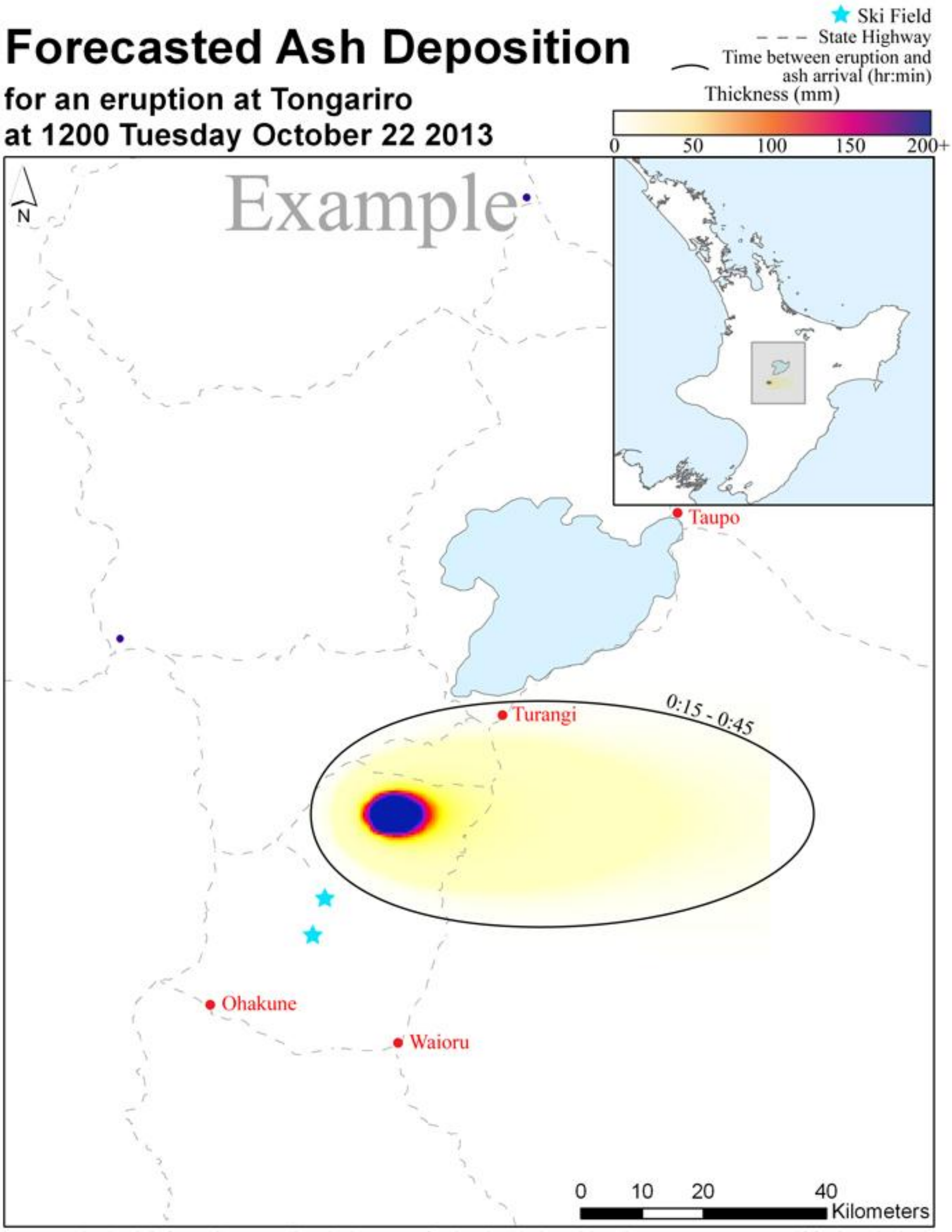
#	Question	I dislike it very much	I am indifferent about it	I like it very much	Total Responses	Mean
1	Use of colour	2	3	31	36	2.81
2	Ski fields	2	23	11	36	2.25
3	Names of towns and cities	1	4	31	36	2.83
4	Locations of towns and cities	0	3	33	36	2.92
5	Inset map	2	16	18	36	2.44
6	Scale bar	1	9	26	36	2.69
7	Ash thickness scale bar	0	4	32	36	2.89
8	Disclaimer	1	20	15	36	2.39
9	Information regarding hazards of volcanic ash	3	9	24	36	2.58
10	Information concerning ash in the air	2	8	25	35	2.66
11	Forecasted ash depths table	0	5	31	36	2.86
12	Wind data	3	12	20	35	2.49
13	Critical thresholds section	5	9	19	33	2.42
14	Date and time of eruption	0	8	28	36	2.78
15	State highways	1	10	25	36	2.67

18. Any comments you wish to make concerning the map you just critiqued?

Excluded

Forecasted Ash Deposition

for an eruption at Tongariro
at 1200 Tuesday October 22 2013



For more in-depth information regarding the impacts of volcanic ash deposition (how to prepare yourself for it and what to do during it) please visit http://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/Eruption!-What-to-do

This is a model of how the ash will be deposited on the ground at the end of the event. For information concerning how the ash will interact with air currents and how this will affect air travel please visit http://www.caa.govt.nz/meteorology/Volcanic_Ash_Advisory_System.htm

Disclaimer: This forecast has been created using estimated values. It is possible that the ash will be deposited in a different manner than is depicted here. This forecast is supplied only as an aid for decision making and as such the issuing organisation bears no responsibility for any decisions made based upon this forecast.

For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Ohakune	0 – 1	0:30 – 1:00
Taupo	0 – 1	0:45 – 1:15
Turangi	0 – 10	0:15 – 0:45
Waioru	0 – 1	0:30 – 1:00

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs of residential homes may begin to sag or collapse under the weight of the ash (long-span roofs may begin to suffer damage before this point). It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

Background information:

This map was created using a model which takes into account the eruption volume, column height, ash grain size distribution, eruption duration, and wind conditions. The column height is estimated at the time of eruption. The eruption volume, grain size distribution, and eruption duration are chosen based on the history of each volcano and what is typical for an eruption of this size. The wind conditions used are current conditions which have been supplied by Metservice within the last 12 hours. The model also accounts for all forecasted changes in wind patterns for the duration of the event. This map is produced on the assumption that all of these values are accurate and that the wind will develop as forecasted.

19. Please critique each aspect of the map

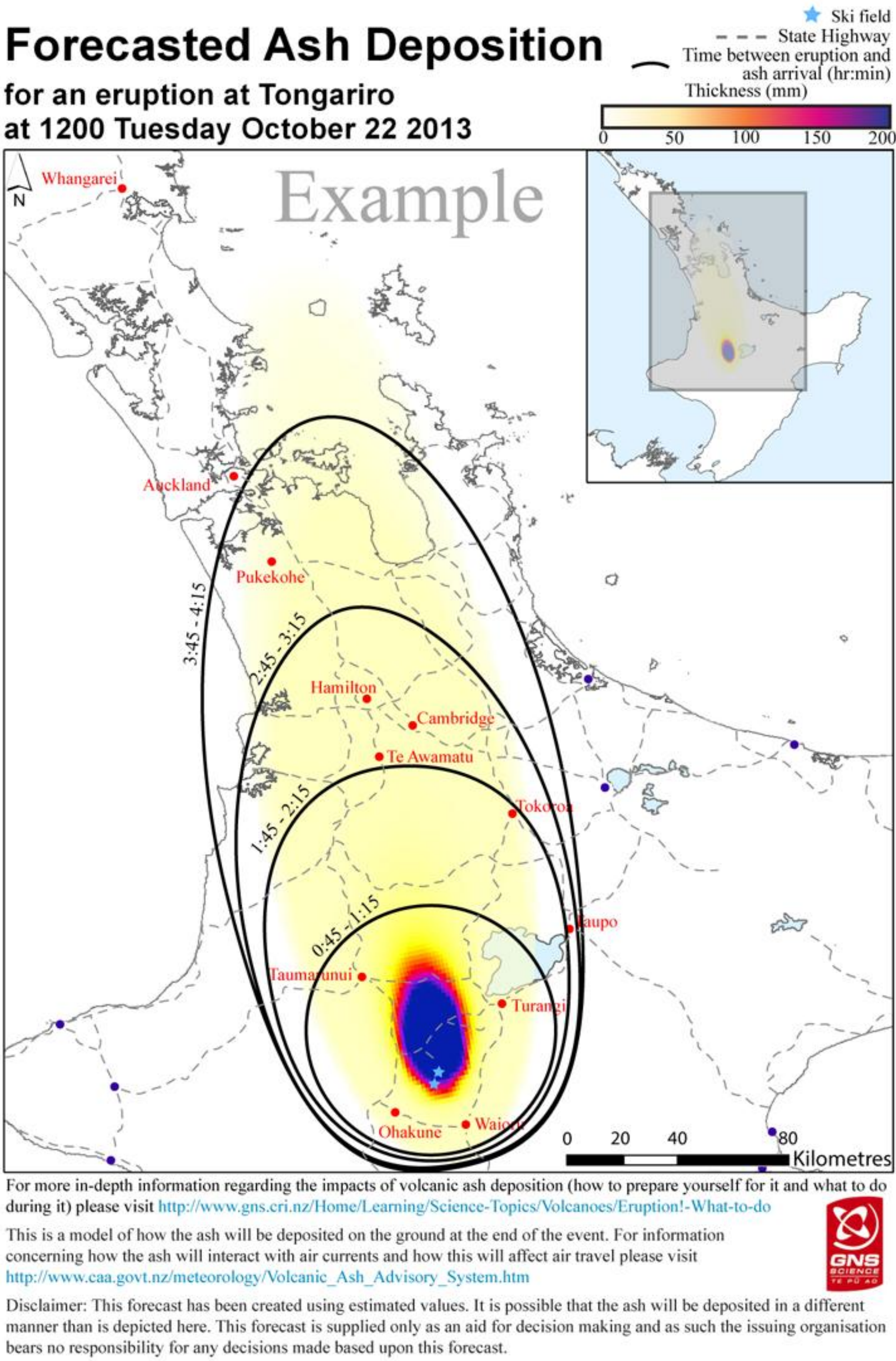
#	Question	I dislike it very much	I am indifferent about it	I like it very much	Total Responses	Mean
1	Use of colour	2	3	31	36	2.81
2	Ski fields	1	21	14	36	2.36
3	Names of towns and cities	0	4	32	36	2.89
4	Locations of towns and cities	1	5	30	36	2.81
5	Inset map	2	8	26	36	2.67
6	Scale bar	2	7	26	35	2.69
7	Ash thickness scale bar	0	4	31	35	2.89
8	Disclaimer	1	22	13	36	2.33
9	Information regarding hazards of volcanic ash	3	7	25	35	2.63
10	Information concerning ash in the air	3	8	25	36	2.61
11	Forecasted ash depths table	0	8	28	36	2.78
12	Wind data	3	9	23	35	2.57
13	Critical thresholds section	5	7	21	33	2.48
14	Date and time of eruption	0	3	33	36	2.92
15	State highways	2	11	22	35	2.57

20. Any comments you wish to make concerning the map you just critiqued?

Excluded

21. Is there anything which you feel should have been included on the maps but was not?

Excluded



Forecasted Ash Deposition
for an eruption at Tongariro
at 1200 Tuesday October 22 2013
Ski field
State Highway
Time between eruption and ash arrival (hr:min)
Thickness (mm)
0 50 100 150 200+
Example
N
Whangarei
Auckland
Pukekohe
Hamilton
Cambridge
Te Awamatu
Tokoroa
Taupo
Taumarunui
Turangi
Ohakune
Waiouru
3:45 - 4:15
2:45 - 3:15
1:45 - 2:15
0:45 - 1:15
0 20 40 80
Kilometres
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For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Auckland	5-15	4:00 – 4:30
Cambridge	15-45	2:00 – 2:30
Hamilton	15-45	2:15 – 2:45
Ohakune	15-45	0:15 – 0:45
Pukekohe	5-25	3:15 – 3:45
Taumarunui	35-75	0:15 – 0:45
Taupo	0-2	1:15 – 1:45
Te Awamatu	20-50	2:00 – 2:30
Tokoroa	5-30	1:30 – 2:00
Turangi	25-65	0:15 – 0:45
Waioru	20-50	0:15 – 0:45
Whangarei	0-2	6:15 – 6:45

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

Note: Any instruction given by Civil Defence takes precedence over the information found here.

Any ash present – Please keep yourself and your animals protected and close all doors and windows. Ash is extremely abrasive and even small amounts can cause respiratory distress and skin irritation. If you must be outside make sure you are covered up and using an airborne particulate mask which meets certification.

Several millimetres – Avoid driving except in cases of extreme emergency. The thin layer of ash on the ground results in a loss of traction for cars which can easily lead to an accident. Also, your visibility will be reduced, and the abrasiveness of the ash can damage parts of an automobile such as the engine and brakes.

10 millimetres – You may experience a loss of electricity and other utilities, as at this point the ash has built up enough to cause flashover on the power lines.

>200 millimetres – Some roofs of residential homes may begin to sag or collapse under the weight of the ash (long-span roofs may begin to suffer damage before this point). It is important to clean the ash off of roofs as soon as it is acceptably safe to do so. Take extreme care as ash will cause roofs and ladders to be more slippery than normal.

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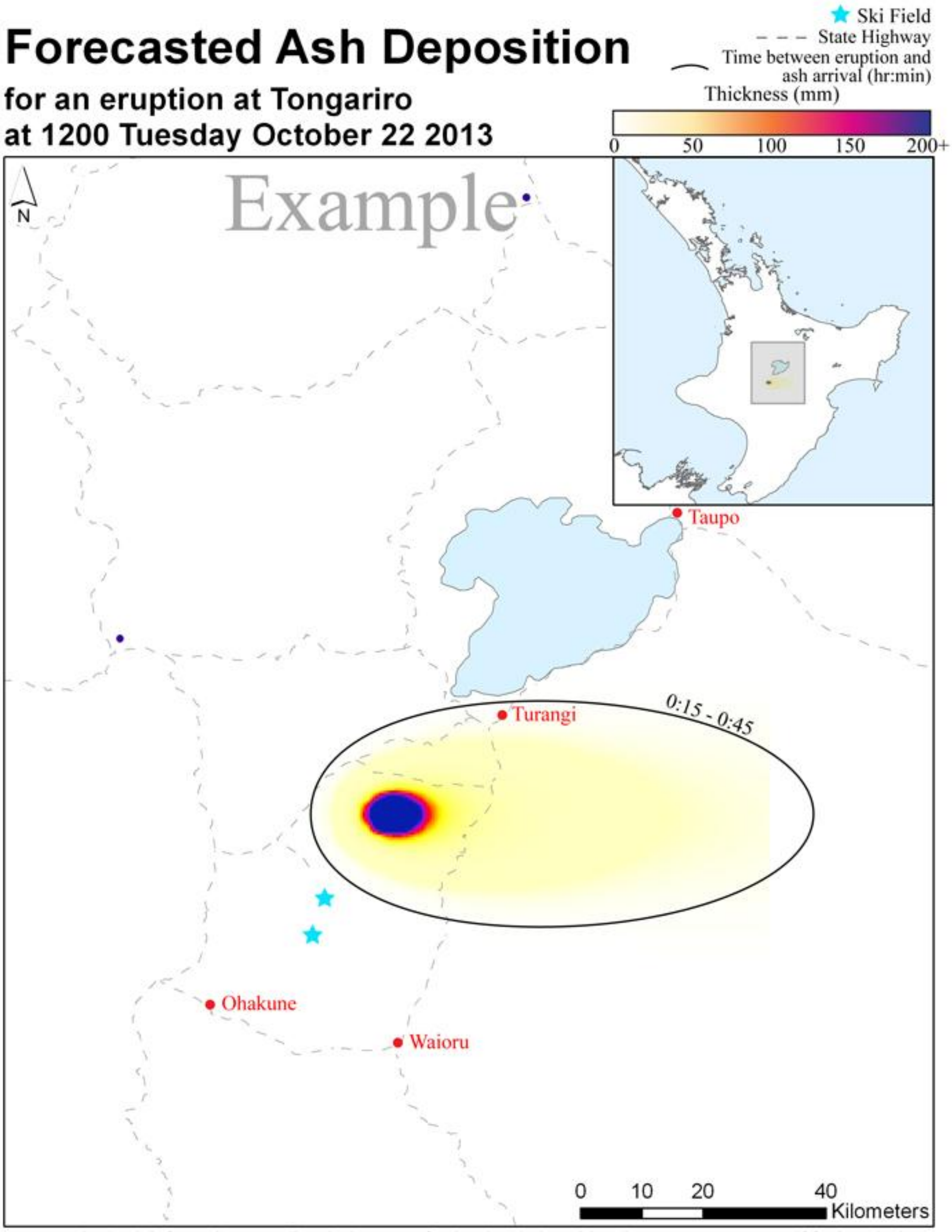

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For an eruption at Tongariro
At 1200 Tuesday October 22 2013

Towns and cities affected

Town	Depth (mm)	Time between eruption and arrival (hr:min)
Ohakune	0 – 1	0:30 – 1:00
Taupo	0 – 1	0:45 – 1:15
Turangi	0 – 10	0:15 – 0:45
Waioru	0 – 1	0:30 – 1:00

Due to the uncertainty in the model the depths and times are presented as ranges rather than exact figures. The depth range represents the amount that each population centre in general can expect, regardless of location within the centre.

Estimated impacts:

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22. Based on viewing these maps, how much trust do you place in the accuracy of them?

#	Answer		Response	%
1	I expect the ash deposition to match the map		2	6%
2	I expect some variability, but I assume that the ash deposition will be similar to the map		11	31%
3	I believe the map to be a best estimate and that there is the potential for the ash to be deposited differently than how it is shown on the map		22	61%
4	I believe that the map shows one possible pattern of deposition, but that it is likely that the ash will be deposited in a different manner than how it is shown on the map		1	3%
	Total		36	100%